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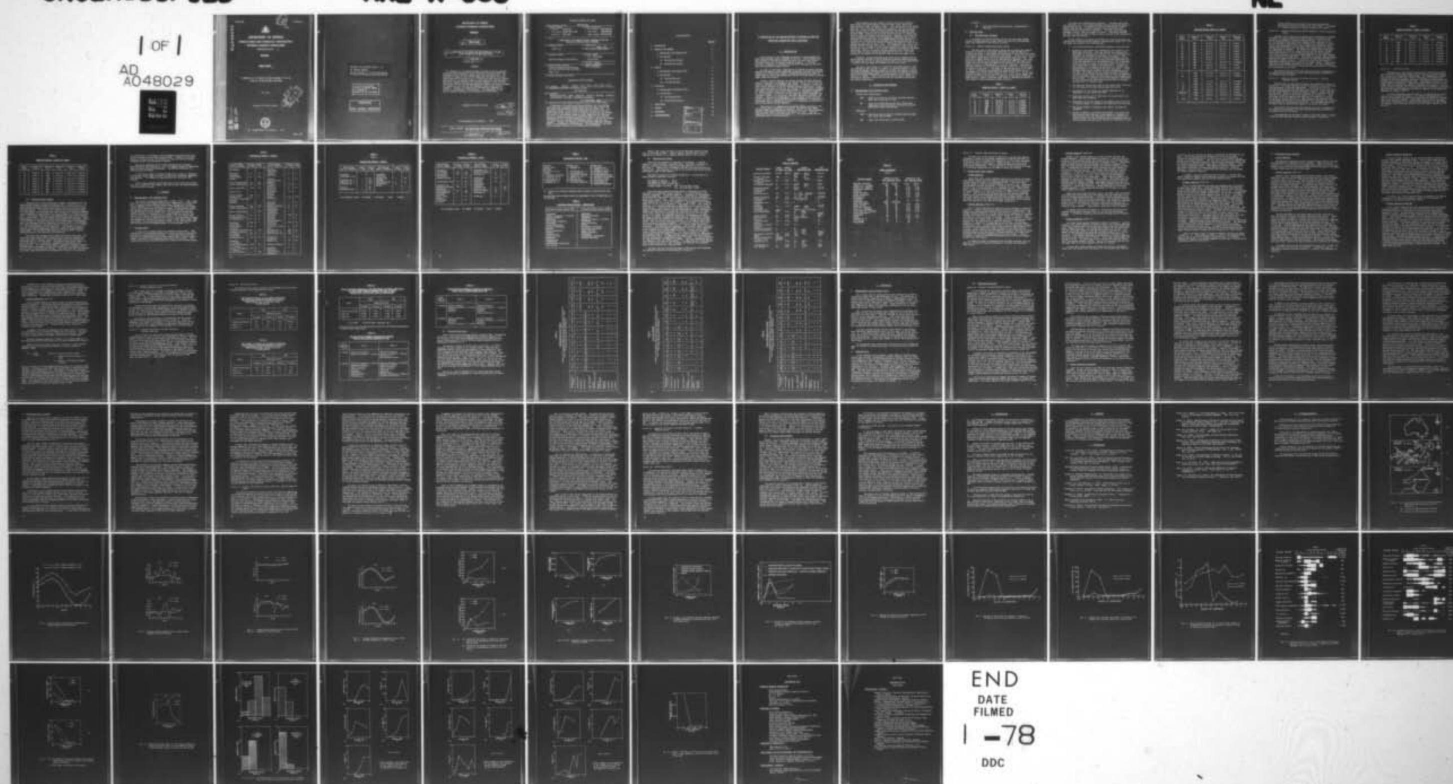

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MELBOURNE, VICTORIA

REPORT

MRL-R-688

A COMPARISON OF THE MARINE FOULING OCCURRING AT THE TWO PRINCIPAL AUSTRALIAN NAVAL DOCKYARDS

G.R. Russ

Approved for Public Release

APRIL, 1977

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14 **MRL-R-688**

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ABSTRACT

A comparison of the marine fouling occurring at the two principal Australian Naval Dockyards (Garden Island Naval Dockyard, Sydney and Williamstown Naval Dockyard, Hobsons Bay) has been carried out. The sequences of change in the fouling communities settling on non-toxic panels immersed for periods of up to 12 months at each site are recorded and aspects of successional change in these communities are discussed. Aspects of seasonal variations in fouling intensity at each site are investigated and the fouling intensities (in terms of wet and dry weights of fouling per unit area per unit immersion time) at each site are compared. Finally, the deposition of microfouling organisms ("p[illegible] slime") at Williamstown is investigated. The composition of the [illegible] and the seasonal variations in its deposition are recorded.

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16. *ABSTRACT (if this is security classified, the announcement of this report will be similarly classified):*

A comparison of the marine fouling occurring at the two principal Australian Naval Dockyards (Garden Island Naval Dockyard, Sydney and Williamstown Naval Dockyard, Hobsons Bay) has been carried out. The sequences of change in the fouling communities settling on non-toxic panels immersed for periods of up to 12 months at each site are recorded and aspects of successional change in these communities are discussed. Aspects of seasonal variations in fouling intensity at each site are investigated and the fouling intensities (in terms of wet and dry weights of fouling per unit area per unit immersion time) at each site are compared. Finally, the deposition of microfouling organisms ("primary slime") at Williamstown is investigated. The composition of the slime and the seasonal variations in its deposition are recorded.

C O N T E N T S

A COMPARISON OF THE MARINE FOULING OCCURRING AT THE TWO PRINCIPAL AUSTRALIAN NAVAL DOCKYARDS

1. INTRODUCTION

Marine fouling is the attachment and growth of marine animals and plants upon man-made objects submerged in the sea. Such fouling causes most problems on the hulls of ships and boats, on buoys, wharf piles, underwater cables and in seawater pipes and conduits. It is also particularly damaging to underwater anticorrosive coatings and may interfere with underwater acoustic devices.

As early as 1952 nearly 2,000 species of animals and plants had been reported from marine fouling communities throughout the world (see 'Marine Fouling and its Prevention' (1952)), including representatives from 13 animal phyla as well as representatives from all the major groups of marine algae, fungi and bacteria.

Within a fouling community the species present and their densities depend on geographic, environmental and seasonal factors plus the type of substrate available for attachment (Zann 1972). In general a clean, non-toxic surface immersed in the sea initially becomes covered with a slime film consisting mainly of bacteria and diatoms with algal spores, inorganic and organic particles and protozoa also present. This passive settlement of 'primary fouling' facilitates, though it is not absolutely necessary for the attachment of larvae of the more important fouling organisms, the 'secondary foulers' e.g. barnacles, serpulids, Bryozoans, Ascidians, and Molluscs. Finally the establishment of the secondary foulers provides shelter and food for such organisms as errant polychaetes, crustaceans and nudibranchs which, although not attached to the substrate do constitute a part of the overall fouling community.

This report is a comparison of the marine fouling occurring at the two principal naval dockyards in Australia: the Garden Island Naval Dockyard (GIND) in Sydney Harbour (Latitude 33° 52'S, and the Williamstown Naval Dockyard (WND) in Hobsons Bay (Latitude 37° 52'S). Both are temperate sites on the east coast (Fig. 1). The study period ran from mid-October 1973 to mid-October 1974.

Until recently the only studies on marine fouling in Australian waters dealt with Sydney Harbour (Allen and Wood, 1950; Wood,1950; Wood and Allen, 1958; and Wisely, 1959). Very few studies of the marine fauna and flora of Hobsons Bay have been carried out and as far as can be discerned, no work on marine fouling in Hobsons Bay has been published. This is particularly surprising considering that the Williamstown Naval Dockyard (WND), several yacht clubs and the docking site of certain Bass Strait ferries are located within Hobsons Bay. However, in the last few years an upsurge of interest in the ecology of Hobsons Bay has occurred following the disclosure that the proposed Newport D power station at the northern end of the bay will use bay water for cooling purposes and is expected to heat the top few metres of Hobsons Bay water by 1-2^{o}C on the average (Heated Effluent Study, 1973). The communities most likely to be effected by such a change are the fouling communities on wharf piles and beacons and this has led to the Victorian Fisheries and Wildlife Department initiating a study of the marine fouling organisms within Hobsons Bay (which began at almost exactly the same time as this one - late 1973). Nothing of the Fisheries and Wildlife's work has been published as yet.

Therefore, besides representing the first direct comparison of the marine fouling occurring at the two principal Australian Naval Dockyards, this report may also be of significance in respect of the increased levels of thermal pollution expected in Hobsons Bay in future years.

The aims of this study are to record the principal species of fouling organisms at WND and GIND, to compare the fouling intensity at both sites and investigate seasonal aspects of fouling, and finally to observe the temporal sequences of change and overall biotic successions occurring within the fouling communities on surfaces immersed at both sites over a period of 12 months. Since fouling on the hulls of naval vessels is a particularly important problem the information contained in this report has defence significance.

2. MATERIALS AND METHODS

A. Hydrographic and Rainfall Data

Surface Water Temperatures :

GIND - taken from records of the N.S.W. Maritime Services Board and records kept at GIND.

WND - taken from records kept at the State Electricity Commission of Victoria (SECV) and Materials Research Laboratories (MRL), Maribyrnong.

Chlorinity :

GIND - taken from records of N.S.W. Maritime Services Board and records kept at GIND.

WND - taken from records kept at SECV and MRL.

Rainfall :

WND - taken from Weather Bureau Records, Commonwealth of Australia.

B. Fouling Data

Bl. Macrofouling Studies

To collect the fouling species, 30 cm x 15 cm non-toxic panels (either Polyvinylchloride or steel coated with non-toxic anticorrosive paint) were immersed at both sites in 3 series :

Series (a) - Temporal Sequence/Succession Panels

The major aim of this series of panels was to monitor the temporal sequences of change in the fouling communities at GIND and WND over a 12 month period and to investigate the possibility of true biotic succession occurring at either or both sites over this period. 30 cm x 15 cm x 0.1 cm steel panels coated with a non-toxic anticorrosive paint were used. Each panel had a number affixed to it for identification purposes. Four such panels were immersed in the seawater at both sites (WND and GIND) in mid-October 1973, and a panel was removed from the water at each site after immersion periods of approximately 3, 6, 9 and 12 months. The panels at GIND were attached to a raft and were held at a depth of 1.5 metres below the surface of the water. The panels at WND were bolted to a 2 m length of 'dexion' (aluminium) and suspended by cable beneath Nelson Pier at approximately 1.5 metres below the water level at low tide. As the tidal variation at WND is only of the order of 0.3 - 0.45 m, it was assumed that no great differences in the depth of immersion of the panels at WND and GIND occurred. Table 1 gives the exact dates of immersion and removal of this Temporal Sequence/Succession series of panels.

TABLE 1

IMMERSION PERIODS - SERIES (a) PANELS

Panel Number	Immersion Site	Immersion Date	Removal Date	Immersion Period
31	GIND	20.10.73	8.2.74	3 months
32	GIND	20.10.73	29.4.74	6 months
33	GIND	20.10.73	8.7.74	9 months
34	GIND	20.10.73	9.10.74	12 months
35	WND	4.10.73	22.1.74	3 months
36	WND	4.10.73	10.4.74	6 months
38	WND	4.10.73	3.7.74	9 months
37	WND	4.10.73	1.10.74	12 months

All panels were weighed before immersion. The panels were fixed i.e. preserved, in a 3-4% formalin/sea-water solution within 30 minutes of removal from the sea. The panels at GIND were then placed in sealed plastic bags and sent by express freight to the Paints Laboratory, Materials Research Laboratories, Melbourne. The panels were suitably packaged to protect them from damage in transit. The panels from WND were held in fresh sea-water during the short trip back to the laboratories and were fixed upon arrival.

At the laboratory the panels were placed in a tray of sea-water and examined with a Zeiss binocular magnifier (magnification range x 6 to x 40). Each panel was analysed in the following way.

1. All fouling species were identified, generally to species level.

2. Estimates of the numbers of individuals of each species on the whole panel were made. This was achieved by counting every individual of each species in four 15 cm x 3 cm transects across the panel, two transects on each side of the panel. Each transect covers a total area of 45 square centimetres so that = 180 square centimetres of the total available 900 square the total area examined is 4 x 45/centimetres i.e. 20% of the panel. On any one side of a panel one transect tended to be taken in the top half and the other in the bottom half. However the exact position of a transect was selected so as to give a good representation of the fouling on the panel as a whole. As the fouling on most panels tended to be fairly homogeneous on any one side, this selection did not present any great difficulty. If there were any obvious fouling species in such low numbers as not to be included within the four transects, their numbers were also recorded. An estimate of the total numbers of individuals of each species on the whole panel and each side of the panel was made from the transect counts.

3. The densities (number/unit area) of each species were calculated for both sides of the panel and the panel as a whole.

4. Measurements of the average and maximum dimensions of the individuals of each species were made.

5. Percentage surface cover of each side of the panel and of the whole panel was estimated.

6. Measurements of the wet weight and dry weight (panel oven dried to constant weight) of fouling on the whole panel were recorded.

7. The average height of fouling on each side of the panel was estimated.

8. Finally a complete, qualitative description of the whole panel was recorded, mentioning any obvious aspects of dominance of a particular species, any competitive interactions between and within species, any obvious similarities or dissimilarities with with previously analyzed panels, any obvious differences in the

TABLE 2

IMMERSION PERIODS SERIES (b) PANELS

Panel Number	Immersion Site	Immersion Date	Removal Date	Immersion Period
A	WND	16.11.73	17.12.73	1 month
M2	WND	17.12.73	16.1.74	1 month
M3	WND	16.1.74	20.2.74	1 month
M4	WND	20.2.74	19.3.74	1 month
MV	WND	19.3.74	25.4.74	1 month
M6	WND	26.4.74	29.5.74	1 month
M7	WND	29.5.74	3.7.74	1 month
M	WND	3.7.74	19.8.74 *	1½ months
M9	WND	19.8.74	18.9.74	1 month
J1	WND	18.9.74	21.10.74	1 month
B	GIND	9.11.73	11.12.73	1 month
M2	GIND	11.12.73	8.2.74 *!	2 months
	GIND			
S	GIND	19.2.74	1.4.74 *	1½ months
S5	GIND	1.4.74	29.4.74	1 month
S6	GIND	1.5.74	29.5.74	1 month
Z7	GIND	29.5.74	8.7.74	1 month
Bakelite	GIND	8.7.74	12.8.74	1 month
Z	GIND	12.8.74	25.9.74 *	1½ months
Z10	GIND	25.9.74	21.10.74	1 month

fouling community on each side of the panel and generally describing in detail the whole nature of the panel. An example of a complete analysis of a panel is shown in the results.

Series (b) - Seasonal Variations in Fouling Intensity - Monthly Immersion Panels

The major aim of this series of panels was to determine any seasonal variations in fouling intensity at GIND and WND and to determine the seasons of settlement of individual fouling species. 30 cm x 15 cm x 0.3 cm Polyvinylchloride panels were immersed in the sea-water at each site for periods of approximately one calendar month throughout the year. The PVC was sandblasted on both sides to roughen the surface and thus enhance larval settlement and each panel had a number and letter affixed for identification purposes. The panels were weighed before immersion. The GIND panels were held at 1 metre depth on the raft whilst the WND panels were placed on a 1.5 cm diameter aluminium rod and suspended by wires from the pipes at the base of Gellibrand Pier so that they remained 1 metre below the low water mark. This series of monthly immersion panels began in mid-November 1973 and the exact date of immersion and removal of each panel is shown in Table 2. It will be noted that the period of immersion of some panels is not exactly one calendar month. These variations were unfortunately unavoidable at the time. The panel immersed at GIND from 8.7.74 to 12.8.74 was a smooth bakelite panel because a PVC panel was not available at the time.

Upon removal from the water these panels were fixed, transported to the laboratory and analyzed in exactly the same manner as described for the previous series of panels.

Series (c) - Seasonal Variations in Fouling Intensity - 3 Monthly Immersion Panels

The major aims of this series of panels were identical to those in series (b). The longer immersion period was designed to gain data on the settling seasons of slow settling species. 30 cm x 15 cm x 0.3 cm polyvinylchloride panels were immersed in the sea-water at each site for periods of approximately 3 months throughout the year. However the data for the first 3 months of this series (October 1973 to January 1974) were taken from the panels in series (a) (Panels 31 and 35 Table 1). Apart from these latter two panels, which were held at a depth of 1.5 metres, the series (c) panels were held at 1 metre depth on the GIND raft, and 1 metre below low water mark in the same way and at the same site at WND as was mentioned for the WND series (b) panels. The following table gives the exact dates of immersion and removal of the series (c) panels.

Upon removal from the water these panels were fixed, transported to the laboratory and analyzed in exactly the same manner as described for the previous (a) and (b) series.

For comparison with the above 3 series of non-toxic panels, 8 panels coated with anti-fouling formulations were included in the project.

TABLE 3

IMMERSION PERIODS - SERIES (c) PANELS

Panel Number	Immersion Site	Immersion Date	Removal Date	Immersion Period
31	GIND	20.10.73	8.2.74	3 months
1S	GIND	15.2.74	29.4.74	2½ months
2S	GIND	29.4.74	12.8.74	3 months
3Z	GIND	16.8.74	21.10.74	2 months
35	WND	4.10.73	22.1.74	3½ months
1M	WND	13.2.74	21.5.74	3 months
2M	WND	21.5.74	19.8.74	3 months
4M	WND	19.8.74	23.10.74	2 months

Series (d) - Antifouling Panels

The major aim of this series of panels was to compare the performance of advanced antifouling systems with the non-toxic surfaces (series (a), (b) and (c)), immersed at GIND and WND. Two commercially available antifouling systems were used: Paint A containing 12.6% Tributyl tin fluoride as the toxic component and Paint B containing 16-17% Tributyl tin fluoride plus the algicide Ametryne (3%). Percentages are given on a dry weight basis for the paints. Eight steel panels (30 cm x 15 cm x 0.1 cm) coated with an aluminium, anticorrosive undercoat were prepared. Four of these had Paint A applied (2-3 coats) and the other four Paint B (2-3 coats). The dates and sites of immersion, the dates of removal and the periods of immersion are shown in Table 4.

The WND antifouling panels were held at the same depth and at the same site as the series (a) panels. The GIND antifouling panels were held at 2 metre depth (0.5 metres below the series (a) panels) at the same site as the series (a) panels. Upon removal from the water the panels were fixed, transported to the laboratory and analyzed in the same manner as described for the previous series of non-toxic panels (Series (a), (b) and (c)).

TABLE 4

IMMERSION PERIODS - SERIES (d) PANELS

Panel Number	Antifouling Paint	Immersion Site	Immersion Date	Removal Date	Immersion Period
39	Paint A	GIND	20.10.73	29.4.74	6 months
40	Paint A	GIND	20.10.74	9.10.74	12 months
43	Paint B	GIND	20.10.73	29.4.74	6 months
44	Paint B	GIND	20.10.73	9.10.74	12 months
41	Paint A	WND	4.10.73	18.4.74	6 months
42	Paint A	WND	4.10.73	1.10.74	12 months
45	Paint B	WND	4.10.73	10.4.74	6 months
46	Paint B	WND	4.10.73	1.10.74	12 months

B2. Microfouling Studies

The major aim of these studies was to monitor the deposition of the marine primary slime on non-toxic surfaces at WND. Sixteen 7.5 cm x 5 cm optical glass microscope slides were attached to a 45 cm x 35 cm piece of polyvinylchloride (PVC) by double sided tape so that only one face of each slide was exposed. The PVC was then lowered into the sea-water by means of a fibre glass rope and guided down into the water by a vertical aluminium railing (similar to a guillotine) to a constant depth of 13" below low water mark. The railing system was attached approximately fifty metres from the base of Nelson Pier. The glass slides faced outward from the pier. Before being immersed the slides were cleaned with phosphate free detergent, rinsed in four changes of distilled water and finally sterilised by autoclaving. Each slide programme involved immersing the sixteen slides at the beginning of a month and removing a slide after 2 hours, 4 hours, 1, 2, 3, 4, 7 days etc., up to approximately 31 days immersion. Upon removal the primary slime on the slide was immediately fixed by passing the slide through a bunsen flame. The slide was then placed in a sterile plastic bag and transported back to the laboratory for examination.

The slides were examined with a Nikon S-UK optical microscope. For each slide twenty random fields of magnification x300 were examined and counts were made of diatoms, protozoa and algal spores and estimates of percentage surface cover were made. Diatoms were identified, usually to genus, and counts of the numbers of individuals of each species were generally made. From these random samples, estimates of diatoms, protozoa and algal spores per square centimetre were made and an estimate of total surface cover of the slide was recorded. The slides were then Gram-stained and twenty random X1000 fields were examined for bacteria in the same way

as outlined above for diatoms so that an estimate of bacterial cover per square centimetre could be made for each slide. Generally, after about ten days, the bacteria were too difficult to count as they were usually overgrown by heavy concentrations of diatoms.

Once fully examined with the optical microscope in the manner described above, each slide had a 1 cm x 1 cm sample removed for examination under the Scanning Electron Microscope. The SEM was used mainly for identification of diatoms.

In the latter stages of a slide program (16 to 31 days of immersion) macrofouling usually began to settle e.g. barnacles, ascidians, amphipods and serpulids. The numbers of these groups on each slide were also recorded.

Three 'slide programs' (as outlined above) were carried out in 1974. They were in February (late summer), May (late autumn) and August/September (late winter/early spring).

3. RESULTS

A. Hydrographic and Rainfall Data

This data is represented graphically in Figs. 2 and 3. Fig. 2 compares the average mean monthly surface water temperatures at GIND and WND. Fig. 3 compares the mean monthly surface water temperatures throughout 1973/74 (November 1973 to October 1974) at GIND and WND with the average surface water temperatures for these two areas; the approximate average mean monthly surface water chlorinity at GIND with the data collected between November 1973 and October 1974; the approximate average mean monthly chlorinity of sea-water at 6 ft depth at WND with data for sea-water at 16 ft depth collected between November 1973 and October 1974; (the average chlorinity values for both sites are only approximate because the averages were calculated from only 2 years' (GIND) and 2½ years' (WND) measurements) the average mean monthly rainfall at the GIND and WND sites with the data collected between November 1973 and September 1974.

B. Fouling Data

A total of 97 fouling species were recorded in this study. This consisted of 71 macrofouling species, 38 of which occurred at both sites, plus 26 micro-fouling species from WND. The fouling species observed consisted of representatives from 8 invertebrate phyla, 3 phyla of macro-algae, one phylum of micro-algae (diatoms) and marine bacteria. Full species lists of macro and microfoulers are shown in the following tables.

TABLE 5

MACROFOULING SPECIES - ANIMALS

Macrofouling Species (Animals)	Occurs at GIND	Occurs at WND	Macrofouling Species (Animals)	Occurs at GIND	Occurs at WND
ASCIDIACEA			*CRUSTACEA (Amphipoda)*		
Botryllus schlosseri	++	+++	*Caprella equilibria*	++	++
Botrylloides leachii	++	+++			
			Caprella septentrionalis	++	++
Sub F. Polyclininae	++	+++	*HYDROZOA*		
Ciona intestinalis	++	+++	*Tubularia australis*	+++	+
Pyura stolonifera	++++	+++	*Eudendrium generalis*	++	++
Styela clava	+	-	*Halocordyle distacha*	+++	-
Styela plicata	+++	+	*MOLLUSCA*		
Unidentified Multicolor (Diplosoma?) Colonial	+++	++	*Mytilus planulatus*	+++	++++
BRYOZOA			*Electroma georgiana*	-	++
Bugula neritina	+++	+++	*Modiolus confusus*	++	++
Bugula avicularia(?)	+++	-	*Crassostrea commercialis*	++	-
Bugula stolonifera	-	+++	*POLYCHAETA (Serpulidae)*		
Bugula fulva(?)	++	++	*Hydroides norvegica*	++++	++
Scrupocellaria sp.					
Tricellaria sp.	++	+	*Hydroides brachyacantha(?)*	-	+
Zoobotryon pellucidus	+++	-	*Galeolaria caespitosa*	+++	++
Schizoporella unicornis	+++	-	*Pomatoceros terrae novae*	+	+++
Cryptosula pallasiana	++	+++	*Spirorbis sp. 1*	+++	++
Conopeum reticulum	++	-	*Spirorbis sp. 11*	+++	++
Watersipora subovoidea	+++	-	*Spirorbis sp. 111*	+++	-
Bowerbankia sp.	++	++	*Mercierella enigmatica*	-	+++
CRUSTACEA (Cirripedia)			*Serpula sp.*	++	++
Balanus variegatus v. cirratus	++++	+++	*Salmacina dysteri*	++	-
Balanus variegatus v. communis	+++	+	*Hydroides Lunulifera*	+	-
Elminius modestus	-	++++	*Spirobranchus giganteus*	+	-

TABLE 5

(Cont.)

MACROFOULING SPECIES - ANIMALS

Macrofouling Species (Animals)	Occurs at GIND	Occurs at WND	Macrofouling Species (Animals)	Occurs at GIND	Occurs at WND
CRUSTACEA			*POLYCHAETA*		
(Amphipoda) cont.			*(Spionidae)*		
	-	++	*Polydora spp.*	+	+++
Amphithoe sp. 1	-	+++	*PORIFERA*		
Amphithoe sp. 11	-	+++	*Halichondria sp.*	-	++
Corophium sp.	-	++	*Unidentified Sponge*	++	-
Aora sp.	-	++			
Ischyroceros sp.	-	++			

++++ Dominant Fouler +++ Common ++ Present + Rare - Absent

TABLE 6

MACROFOULING SPECIES - ALGAE

Macrofouling Species (Algae)	Occurs at GIND	Occurs at WND	Macrofouling Species (Algae)	Occurs at GIND	Occurs at WND
CHLOROPHYTA			*RHODOPHYTA* cont.		
Ulva lactuca	+++	+++	*Epimenia wilsonis*	++	-
Enteromorpha intestinalis	+++	+++	*Ceramium* sp.	++	++
Bryopsis plumosa	+	++	*Centroceros clavulatum*	+++	+
Chaetomorpha aerea	++	++	*Corallina officinalis*	++	-
Cladophora sp.	++	++	*PHAEOPHYTA*		
Dictyota dichotoma	+++	++	*Giffordia* sp.	+	+++
RHODOPHYTA			*Ectocarpus* sp.	++	++
Polysiphonia sp.	+++	+++	*Ecklonia radiata*	++	-
Medeiothamnion protensum	+	+++	*Sargassum* sp.	++	-
Bangia fusco purpurea	-	++	*Padina* sp.	+	-
Grateloupia filicina	-	++			

++++ Dominant fouler +++ Common ++ Present + Rare - Absent

TABLE 7

MICROFOULING SPECIES - WND

BACTERIA	*DIATOMS* cont.	*DIATOMS* cont.
Gram-ve rods	6. *Synedra sp.*	18. *Licmophora sp.*
PROTOZOA	7. -	21. *Amphora sp.* 111
Vorticella (?) sp.	10. *Pleurosigma sp.* 1	31a *Nitzschia sariata*
DIATOMS	11. *Pleurosigma sp.* 11	31b *Nitzschia sigma*
1. *Nitzschia closterium*	12. *Achnanthes longipes*	34. *Grammatophora marina*
3. *Navicula (?) sp.*	13. *Amphora sp.* 11	46. *Bacillaria paxillifer*
4. *Nitzschia sp.* 1.	14. *Melosira sp.*	48. *Trachyneis aspera*
5A *Amphipleura sp.*	16. *Rhizosolenia sp.*	50. *Asterionella sp.*
5B *Amphora sp.* 1.	17. *Cocconeis scutellum*	52. *Skeletonema sp.*
		54. *Nitzschia longissima*

NB. Diatoms were initially numbered before definite identifications were made.

The principal macro-fouling species in approximate order of importance are listed below.

TABLE 8

PRINCIPAL FOULING SPECIES - GIND AND WND

Principal Fouling Species (WND)	Principal Fouling Species (GIND)
CIRRIPEDIA	*SERPULIDAE*
Balanus variegatus v. cirratus	*Hydroides norvegica*
Elminius modestus	*CIRRIPEDIA*
SERPULIDAE	*Balanus variegatus v. cirratus*
Mercierella enigmatica	*ASCIDIACEA*
ASCIDIACEA	*Pyura stolonifera*
Ciona intestinalis	*BRYOZOA*
Botryllus schlosseri	*Schizoporella unicornis*
MOLLUSCA	*Watersipora subovoidea*
Mytilus planulatus	*Bugula neritina*
BRYOZOA	*Bugula avicularia*
Cryptosula sp.	*CHLOROPHYTA*
Bugula neritina	*Enteromorpha intestinalis*
SPIONIDAE	*Dictyota dichotoma*
Polydora spp.	
CHLOROPHYTA	
Enteromorpha intestinalis	
Ulva lactuca	

Tables 5 and 6 show that many of the macrofouling species recorded occur at both GIND and WND. Table 8 however, indicates that there is a significant difference in the dominant fouling forms at the two sites.

B1. Macrofouling Data

Each panel was analyzed as described in the Method. A typical example of a panel analysis is provided here. The panel in question is panel 32, series (a) 6 month Immersion at GIND (20.10.73 to 29.4.74 See Table 1). Tables 9 and 10 summarise the data collected from panel 32 (Series (a)). The following is a copy of the detailed description of this panel made as part of the analysis.

The panel is dominated by *Balanus variegatus v. cirratus* and to a lesser extent by *Hydroides norvegica*.

Wet Weight of Fouling = 750 g.
Dry Weight of Fouling = 420 g.
% Surface Cover Sth. 98% Nth. 99%.
Average Height of Fouling Nth. 10-12 mm (Max. 21 mm)
Sth. 10-11 mm (Max. 19 mm).

After six months immersion *Balanus* seems to have taken over from *Hydroides* as the dominant fouling organism. At 3 months *Hydroides* was distinctly dominant. The *Balanus* seem to be squeezing out the *Hydroides* and overgrowing them, probably reflecting the slower but more purposeful growth rate of the *Balanus*. Thus the whole panel is much darker with less white tubes showing. This trend is indicated in the following figures: 6 MONTH PANEL (No. 32) % Area with barnacle > 7 mm diameter = 91%, 3 MONTH PANEL (No. 31) % Area with barnacle > 7 mm diameter = 63%. This change in dominance of the fouling groups may be significant in the overall successional process. There are now very few algae present. *Pyura stolonifera* seems to be amazingly frequent although individuals are small, *Schizoporella* numbers seem fewer than at 3 months and *Zoobotryon* has become very common in the last 3 months and individuals are quite large (e.g. 12 cm long). *Bugula's* are present in reasonable numbers but the dimensions are small. Ascidians in general, although not approaching the significance of *Balanus* and *Hydroides* are nevertheless quite frequent (both solitary and colonial forms) - but they are not quite as prevalent as on the WND six month panel. The low numbers of *Balanus variegatus v. communis* are probably due to the difficulty of distinguishing them from var. *cirratus* under the crowded conditions. The barnacles are beginning to show definite signs of crowding as is indicated by the greater height/diameter ratio for 6 months immersion (0.99) compared with 3 months immersion (0.88). Bryozoa are not major foulers (except perhaps *Zoobotryon)*. The relative absence of algae is interesting because the panels are held at a depth suitable for algal growth, with plentiful light. It seems that the animal fouling may be so robust and fast growing as to mechanically exclude the algae. As usual *Halocordyle* is found mainly near the edges of the panel. The light *Bowerbankia* mat is very similar to that seen on WND panels. In summary *Balanus* is now dominant after 6 months and seems to have 'squeezed' the *Hydroides* into isolated pockets and eventually has overgrown them".

The data from each macrofouling panel in this project were tabulated and described in detail as outlined above for Panel 32.

TABLE 9

PANEL 32 ANALYSIS

Species Present	Number on Panel	Number/ sq. inch	Average Dimensions (mm)			Max. Dimensions (mm)
Hydroides norvegica	23,100	160.42	length 18.5	width (0.75)		32(1.0)
Balanus variegatus v. cirratus	1395	9.4	diam. 9	ht. (8.95)		14(15)
Balanus variegatus v. communis	30	0.20	9(8)			12(8)
Galeolaria caespitosa	40	0.28	length 13	width (1)		15(1)
Salmacina dysteri	400	2.75	8(0.2)			12(0.3)
Spirobranchus giganteus	1	-	22(3)			
Bugula neritina	120	0.83	ht. 7.3	wdth. (4.8)	branches 10.7	15(11)30
Bugula avicularia	305	2.11	5.6	(3)	18	17(10)80
Schizoporella unicornis	15	0.10	Colony diameter 7.5			15
Watersipora sub-ovoidea	5	0.03	6			7
Zoobotryon pellucidus	115	0.78	length 44	width (17)		120(45)
Bowerbankia mat.	light	-	zooecia 0.6 - 1.5 mm ht.			
Pyura stolonifera	225	1.56	ht. 8	width (5.9)		16(12)
Styela plicata	30	0.20	9.5	(4)		18(7)
White Colonial Ascidian	40	0.28	Colony diameter 10.6			18
Yellow Colonial Ascidian	125	0.87	12.6			18
Multicolour Colonial Ascidian	20	0.15	6.2			13
Botryllus schlosseri	1	-	5			-
Ciona intestinalis	2	-	ht. 30	width (18)		35(18)
Halocordyle distacha	135	0.94	11.5	(3.5)		30(10)
Sponge	140	0.97	3(1)			6(2)
Caprella equilibria	present	-	-			
Cirratulid worm	present	-	-			
Bryopsis sp. 11	5	0.03	ht. 2	width (1)		4(1)
Polysiphonia sp.	5	0.03	3	(1.5)		5(2)
Ulva lactuca	10	0.07	2	(1.5)		3(2)

TABLE 10

PANEL 32 ANALYSIS

(Cont.)

Species Present	Number on Panel Nth. Side	Number on Panel Sth. Side	Number/sq. inch Nth. Side	Number/sq. inch Sth. Side
Hydroides norvegica	12,350	10,750	171.5	149.5
Balanus var. cirratus	555	840	7.7	11.7
Balanus var. communis	10	20	0.14	0.28
Galeolaria caespitosa	15	25	0.20	0.35
Salmacina	400	0	5.5	-
Bugula neritina	85	80	1.18	1.18
Bugula avicularia	85	220	1.18	3.05
Schizoporella	10	5	0.14	0.07
Watersipora	3	2	-	-
Zoobotryon	95	20	1.3	0.28
Bowerbankia mat.	light	light-med.	-	-
Pyura stolonifera	135	90	1.88	1.25
Styela plicata	10	20	0.14	0.28
White Col. Ascidian	10	30	0.14	0.42
Yellow Col. Ascidian	45	80	0.63	1.11
Multicolour Col. Ascidian	10	10	0.14	0.14
Ciona intestinalis	2	0	-	-
Halocordyle	85	50	1.18	0.7
Sponge	50	90	0.69	1.25
Bryopsis sp. 11	5	0	.07	-
Ulva lactuca	10	0	.14	-
Polysiphonia	5	0	.07	-

Series (a) - Temporal Sequence/Succession Panels

The major aim of this series of panels was to monitor the temporal sequences of change in the fouling communities at GIND and WND over a 12 month period and to investigate the possibility of true biotic succession occurring at either or both sites. Figures 4a and b are plots of dry weight of fouling and wet weight of fouling VS immersion period (from 0-12 months) respectively. A full description of the sequences of change in the fouling communities over 12 months at both sites follows.

(1) Garden Island Naval Dockyard

1 Month Immersion

Twenty days after initial immersion (20.10.73) the Series (a) panels were heavily covered with the serpulid (tubeworm) *Hydroides norvegica* in concentrations of around 5 to 6 organisms per cm^2. The tubes had an average length of 10 mm and average diameter of around 0.1 mm. There were also barnacles (*Balanus variegatus v. cirratus*) with an average diameter around 1.5 mm in concentrations of 1-2 organisms per cm^2. After a full month of immersion the *Hydroides* tubes had an average length of 15 mm and an average diameter of 0.5 mm, and occurred in a density of 20 organisms per cm^2. Thus the panel was dominated with the fast growing *Hydroides norvegica* and also had reasonable concentrations of small *Balanus*. The only other foulers of any significance were the bryozoans *Bugula neritina* and *Bugula avicularia* with some *Enteromorpha intestinalis* and *Ulva lactuca* (both Chlorophytes) on the side of the panel facing north.

3 Months Immersion (Panel 31)

After 3 months immersion the panel was totally dominated by *Hydroides norvegica*. Tubes of this species averaged 15-20 mm in length and 0.75 mm diameter and these organisms occurred in a density of 35-40 per cm^2. The average fouling height was 7.5 mm due mainly to the individuals of *Hydroides* settling upon each other and forming a dense network of calcareous tubes resulting in a large dry weight of fouling. *Balanus variegatus v. cirratus* was the next most common fouler at 3 months but this species does not reach anywhere near the significance of *Hydroides norvegica*. The *Balanus* occurred in a density of 1.1 organisms per cm^2 and had an average basal diameter of 7.0 mm. It should be noted here that this species of barnacle is considered close to maturity when it has attained a basal diameter of 7 to 10 mm. Other significant foulers recorded on this panel were the bryozoans *Bugula avicularia* and *Schizoporella unicornis*, some small solitary ascidians (mostly *Pyura stolonifera*, although ascidians on the whole were infrequent) and the algae *Polysiphonia* sp. and *Ulva lactuca*. *Balanus variegatus v. communis, Galeolaria caespitosa* and the hydroid *Halocordyle distacha* were also present.

In summary the panel is dominated with the white calcareous tubes of *Hydroides norvegica* with *Balanus variegatus v. cirratus* the next most common fouler.

6 Months Immersion (Panel 32)

Between 3 and 6 months immersion a distinct change came over the fouling community. The barnacle *Balanus variegatus v. cirratus*, with its slower but more purposeful growth rate gradually took over from *Hydroides norvegica* so that by 6 months *Balanus* was the dominant fouler. The *Balanus* showed a marked increase in basal diameter and seemed to "squeeze" the *Hydroides* tubes between them and eventually the *Balanus* overgrew the tube-worm. Consequently the *Hydroides* counts decreased and their density at 6 months was only 25-30 per cm^2. The average basal diameter of *Balanus variegatus v. cirratus* increased from 7.0 mm to 9.0 mm and the density increased to 1.7 per cm^2. On the 6 month panel the percentage area of fouling with a *Balanus* greater than 7 mm in diameter was 91% compared with a figure of 63% for the 3 month panel. These figures exemplify the dominance of *Balanus* over *Hydroides* after 6 months. The *Balanus* were also beginning to show signs of crowding. Many were packed side by side thus causing a greater increase in height than diameter during growth which is characteristic of crowded barnacles. The height/diameter ratio for *Balanus variegatus v. cirratus* was 0.88 after 3 months immersion and 0.99 after 6 months immersion. The average fouling height of the panel as a whole almost doubled to 10-12 mm.

Apart from *Balanus* and *Hydroides*, quite a few small, *Pyura stolonifera* (8 mm width) were now present, but were nowhere near the importance of the first two fouling species mentioned. Two other solitary ascidians *Styela plicata* and *Ciona intestinalis* were now present. The bryozoans *Zoobotryon pellucidus, Bugula neritina* and *Bugula avicularia* were present in reasonable numbers along with *Schizoporella unicornis, Watersipora subovoidea* and *Bowerbankia* sp. The serpulids *Galeolaria caespitosa* and *Salmacina dysteri* occurred in small numbers. Algae however, were now in very low numbers.

In summary the *Balanus variegatus v. cirratus* had slowly grown and squeezed the *Hydroides norvegica* tubes out of their initial dominant position. The *Balanus* themselves were already showing signs of becoming crowded.

9 Months Immersion (Panel 33)

The trend towards greater dominance of *Balanus variegatus v. cirratus* between 3 and 6 months immersion continued between 6 and 9 months immersion until after 9 months immersion the panel was almost completely covered with large, crowded barnacles. The average basal diameter of the *Balanus* was 10.3 mm, the average height 10.1 mm and the density 1.85 per cm^2. The number of *Hydroides norvegica* tubes had decreased markedly from 25-30 per cm^2 due to the mechanical squeezing and overgrowing tendencies of the barnacles. The crowded conditions of the barnacles at 6 months immersion were even further accentuated at 9 months. The average fouling height had reached 15-16 mm. The percentage area of fouling with barnacles greater than 7 mm in basal diameter was 95%. Most of the barnacles were now dead and empty (80% of the total compared with 50% at 6 months).

The next most common foulers were *Pyura stolonifera* in reasonable numbers and with medium sized individuals (10.8 mm average basal diameter)

but these in no way rivalled the *Balanus* or *Hydroides* for dominance of the panel. The encrusting bryozoan *Schizoporella unicornis* had large individuals over-growing many of the dead *Balanus* and *Cryptosula* was now present in reasonable numbers. The only other bryozoan of any significance was the erect, branching *Tricellaria*, *Styela plicata*, *Salmacina dysteri* and the hydroid *Halocordyle distacha* were also in reasonable numbers. Algae were almost completely absent. High numbers of tertiary foulers had by now become established in between the barnacle shells e.g. caprellid amphipods, cirratulid worms, nereid worms and flatworms, thus increasing the overall community diversity.

In summary, large and crowded *Balanus variegatus v. cirratus* were almost completely dominant whilst *Hydroides norvegica* had dropped into even less significance compared with the 6 month immersion panel.

12 Months Immersion (Panel 34)

After 12 months immersion the panel was dominated with the solitary ascidian *Pyura stolonifera*. Large individuals (average basal diameter 14 mm, average height 13 mm) had formed a thick layer on top of the dead barnacles increasing the average fouling height to 18-20 mm. The increased growth of the *Pyura* also caused a sharp rise in the dry and wet weights of fouling between 9 and 12 months immersion (Figs. 4a and b). The large *Pyura's* covered 70% of the total surface area of the panel compared with only 30% after 9 months immersion. Besides *Pyura* the ascidians *Styela plicata* and *Botryllus schlosseri* were reasonably common. The ascidians had overgrown the dead *Balanus* and the density and average size of these barnacles had not changed markedly from the 9 month panel. If anything they had become a little more crowded and had reduced the numbers of *Hydroides norvegica* even more by squeezing action, thus killing them. 95% of the barnacles were dead and empty. Spionids occurred in quite large numbers in between the *Pyura's* and barnacles but were of little significance as were the serpulids *Galeolaria caespitosa*, *Salmacina dysteri* and *Pomatoceros terrae-novae*. Bryozoans were not well represented with only *Schizoporella unicornis* in reasonable numbers with the *Bugulas* and *Tricellaria* insignificant as foulers compared with the barnacles and ascidians. Algae were again poorly represented with only a few individuals of *Dictyota dichotoma* and *Medeiothamnion protensum* present. The panel was heavily covered with tertiary foulers e.g. cirratulids, pycnogonids, nereids, caprellids and even crabs. In summary the solitary ascidian *Pyura stolonifera* was definitely dominant and had almost completely overgrown the heavy *Balanus* coverage which had dominated the 9 month panel.

Some of the major trends of change in community structure are shown in Figs. 5a - d. Such graphs were used to construct the semiquantitative graph in Fig. 6 which is a schematic representation of the temporal sequences of change in the fouling community at GIND over a 12 month period from October 1973 to October 1974.

(2) Williamstown Naval Dockyard

1 Month Immersion

The WND panels (immersed 4.10.73) initially became covered with heavy concentrations of the barnacle *Elminius modestus*. These occurred in densities of 3-5 per cm^2 and had an average basal diameter of 2-3 mm, thus forming a dense and almost continuous barnacle cover over most of the panels. No other foulers were of note at this stage.

3 Months Immersion (Panel 35)

Between 1 and 3 months immersion a distinct change in the fouling community occurred as is evidenced by the sharp rise in dry and wet weights of fouling (Figs. 4a and b). The *Elminius modestus* layer became almost completely covered with parchment like polychaete tubes of the Family Spionidae (possibly several species of *Polydora*) and several species of solitary and colonial ascidians. The spionid tubes (density 8-9 per cm^2) averaged nearly 20 mm in length and 1 mm in diameter, and overgrew the *Elminius* to such an extent as to kill a large percentage of them (70-80%). The 3 month panel had large bare areas with almost no fouling and these areas had distinct imprints of *Elminius* bases indicating that a large percentage of the *Elminius* had fallen off. Where *Elminius* remained (having an average basal diameter of 4.4 mm) they were mostly covered with spionids and were dead. It seemed likely that once the spionids had overgrown and killed the *Elminius* barnacles, they then attained such large dimensions and caused such enormous wet weights of fouling as to loosen the underlying and weakly attached *Elminius*, thus causing large portions of the fouling to fall off. This same process mentioned here whereby spionids overgrow *Elminius* causing death of the *Elminius* and mass fall off of fouling has also been observed on other panels immersed at WND indicating that it may be a natural occurrence at this site.

The main ascidians on the 3 month panel were *Ciona intestinalis*, *Pyura stolonifera*, *Botryllus schlosseri* and *Botrylloides leachii*. These were also showing a tendency to overgrow the *Elminius* barnacles. The barnacle *Balanus variegatus v. cirratus* occurred as the next most important fouler and unlike the *Elminius* very few were overgrown and dead. The *Balanus* had an average diameter of 6.5 mm and occurred in a density of 0.3 per cm^2. Tube forming amphipods were common foulers along with the serpulids *Mercierella enigmatica* and *Pomatoceros terrae-novae*. Bryozoans occurred frequently although they were not significant, the major representatives being *Bugula stolonifera* and *Bugula fulva*. Three individuals of the common mussel *Mytilus planulatus* were recorded (average shell length 7 mm) and fifteen individuals of the mollusc *Electroma georgiana* (average shell length 12 mm). Virtually no algae were recorded. Finally the panel contained huge numbers of the tertiary foulers *Caprella equilibria* and *Caprella septentrionalis* along with nereids. The average fouling height was 20 mm, which reflected the high concentrations of spionids and ascidians.

In summary, the *spionids* are the dominant foulers after 3 months and have taken over from the *Elminius* barnacles. Ascidians are next in importance followed by *Balanus variegatus v. cirratus*, then amphipods and serpulids.

6 Months Immersion (Panel 36)

As noted in Figs. 4a and b the dry and wet weights of fouling drop between 3 and 6 months immersion at WND. After 6 months immersion the panel was dominated by the barnacle *Balanus variegatus v. cirratus* and the spionids and ascidians, which were dominant at 3 months were almost completely absent. The *Balanus* occurred in densities of 0.9 per cm^2 and had an average basal diameter of 6-7 mm. *Mercierella* tubes averaged 23 mm in length and 1.25 mm in width and occurred in densities of 1.6 tubes per cm^2. The average fouling height was 3-4 mm (c.f. 20 mm at 3 months immersion) which further indicated the lowered significance of large spionids and ascidians. Many small, newly established spionids were nevertheless present and there were also very large numbers of newly established *Elminius modestus* (average basal diameter 1-2 mm). Amphipod tubes, although present were much less prevalent than at 3 months immersion. Other species of serpulids, namely *Hydroides norvegica* and *Pomatoceros terrae-novae* were significant foulers. Bryozoans were poorly represented with only small numbers of *Bugula neritina, Bugula stolonifera* and *Cryptosula* present along with a light mat of *Bowerbankia* sp. As mentioned, ascidians were also poorly represented with only small *Botryllus schlosseri, Ciona intestinalis* and *Pyura stolonifera* present. Small numbers of molluscs (*Mytilus* and *Electroma*) were present but algae were rare.

In summary, the 6 month immersion panel was dominated with *Balanus variegatus v. cirratus* and *Mercierella enigmatica* with spionids and ascidians not occurring as significant foulers.

9 Months Immersion (Panel 38)

After 9 months immersion the panel was dominated with the barnacle *Balanus variegatus v. cirratus* and the serpulid *Mercierella enigmatica*. The *Balanus* occurred in densities of 1.2 per cm^2 with average basal diameters of 8 mm. The *Mercierella* tubes had similar dimensions and existed in similar densities to those recorded for the 6 months immersion panel. Apart from those two dominant foulers, small spionids and *Elminius modestus* also settled. The *Elminius* were in densities of 3 per cm^2 and had an average basal diameter of 1-2 mm, which indicated that they had only recently settled. The fouling community on this panel was very similar to the previous panel. The only significant changes were the increased dominance of *Balanus*, the many new individuals of *Elminius* on the panel and the fact that many of the *Balanus* were now dead and empty. It should be stressed that for the 6 and 9 month immersion panels the *Balanus* were never in crowded conditions and did not rival the *Balanus* coverage at GIND in density or dimensions as is indicated by the difference in dry weight between GIND and WND. The average fouling height had increased slightly to 6-7 mm which probably reflected the upward growth of *Balanus*. As mentioned, the fouling community on the 9 month immersion panel had not changed greatly from that on the 6 month panel so that the other important serpulids, bryozoans molluscs and ascidians at 9 months were similar both in the qualitative and quantitative sense to those observed at 6 months. Once again algae were rare.

In summary the 9 month immersion panel was dominated by *Balanus variegatus v. cirratus* and *Mercierella enigmatica*, particularly *Balanus*. The percentage area of fouling on the panel containing *Balanus* greater than 7 mm in diameter was 65-70% compared with 50-55% at 6 months. There was very little change in the community as a whole between 6 and 9 months except possibly for the increased prevalence of *Balanus* due to growth of these individuals. Finally many *Balanus* were dead on the 9 month panel.

<u>12 Months Immersion</u> (Panel 37)

After 12 months immersion at WND the panel was again dominated with *Balanus variegatus v. cirratus* and *Mercierella enigmatica* but the ascidians *Botryllus schlosseri*, *Botrylloides leachii*, individuals of the sub F. *Polyclininae* and to a lesser extent *Ciona intestinalis* were also important foulers. *Elminius modestus* was next in significance. The *Balanus* had a density of 1.3 per cm^2 and an average basal diameter of 8 mm. Many *Balanus* were dead and empty (54% c.f. 45% after 9 months immersion). The percentage area of fouling on the panel containing barnacles greater than 7 mm in basal diameter was 70-75% and the average fouling height was 6-7 mm. The dimensions and density of *Mercierella* tubes were similar to the previous panel. The only other foulers of significance were the serpulids *Hydroides norvegica* and *Pomatoceros terrae-novae* in small numbers plus the bryozoan *Cryptosula* and small spionids. Tertiary foulers (e.g. nereids and caprellids) were common.

In summary, the panel was dominated with large *Balanus variegatus v. cirratus* which were not crowded but rather, were well spaced. The tubeworm *Mercierella enigmatica* was again important and there was a gradual increase in significance of ascidians, particularly colonial forms.

The major temporal sequences of change in the fouling community at WND between October 1973 and October 1974 are shown schematically in Fig. 7.

Finally a species diversity index was calculated for each fouling community on each of the panels of Series (a) using the formula of Margalef (1968):

$$D' = \frac{S-1}{\log_e N}$$

where D' = Species Diversity Index

S = Number of Species present on panel

N = Number of Individuals present on panel

Fig. 8 is a plot of D' versus immersion period from 0 to 12 months at GIND and WND. It should be noted that only the sedentary fouling species were included in the calculation of D'. The errant, tertiary foulers which shelter in crevices and empty shells and tubes e.g. caprellids, cirratulids, nereids, pycnogonids, flatworms, were *not* included in this calculation. Counts of these organisms would have involved breaking open every barnacle and tubeworm and virtually taking the whole fouling community on the panel apart. This was considered to be a much too laborious and time consuming task. This limitation to the calculation of D' for all the macro-fouling panels (Series (a) to Series (d)) should be kept in mind.

Series (b) - Seasonal Variations in Fouling Intensity: Monthly Immersion Panels

Fig. 9 shows plots of dry weight of fouling (in grams) on 30 cm x 15 cm PVC panels immersed for periods of approximately 1 month, versus month of immersion (from November 1973 to October 1974) at GIND and WND respectively. Fig. 10 shows similar plots of wet weight of fouling (g) on the identical panels above versus month of immersion at GIND and WND respectively. Figs. 9 and 10 are thus comparisons of the seasonal fouling intensity at GIND and WND.

A Species Diversity Index (D' mentioned for the series (a) panels) was calculated for the fouling communities on each monthly immersion panel at each site and this has been plotted against month of immersion of panel in Fig. 11. This graph is thus a representation of the seasonal variation in the diversity of species constituting the fouling communities which settle on panels in the different months of the year at GIND and WND.

More specific representations of the principal settling seasons of individual fouling species are shown in Figs. 12 and 13. These are diagrams of the number of individuals of a particular species on 30 cm x 15 cm PVC panels (both sides) immersed for periods of approximately one month, versus month of immersion (from November 1973 to October 1974).

Series (c) - Seasonal Variations in Fouling Intensity: 3 Monthly Immersion

Figs. 14a and b are plots of dry weight and wet weight of fouling (respectively) on 30 cm x 15 cm PVC panels immersed for periods of approximately 3 months at GIND and WND versus 3 month immersion period. Fig. 15 is a plot of the Species Diversity Index (D') for the fouling communities on 30 cm x 15 cm PVC panels immersed for periods of approximately 3 months at GIND and WND versus 3 month immersion period. This Diversity Index is the same as described for the (a) and (b) series panels. Figs. 16a to d are histograms of the number of individuals of a particular species on 30 cm x 15 cm PVC panels immersed for periods of approximately 3 months versus 3 month immersion period. The three species shown in these figures are ones which do not normally settle in large numbers on panels immersed for only a single month. Figs. 16a and b are for species at GIND. Figs. 16c and d are for species at WND.

Series (d) - Antifouling Panels

The following three tables summarise the performance of the two antifouling systems (i.e. antifouling paints) tested.

TABLE 11

DRY WEIGHTS OF FOULING (g) ON CONTROL (NON-TOXIC) AND ANTIFOULING SURFACES IMMERSED FOR 6 AND 12 MONTH PERIODS (OCT. 1973 TO OCT. 1974) AT GIND AND WND

Panel	GIND		WND	
	Immersion Period			
	6 months	12 months	6 months	12 months
Control (non toxic)	323	762	77.0	101.00
Paint A *	2.9	1.8	1.0	1.2
Paint B **	0.72	10.4	0.9	10.2

TABLE 12

WET WEIGHTS OF FOULING (g) ON CONTROL (NON-TOXIC) AND ANTIFOULING SURFACES IMMERSED FOR 6 AND 12 MONTH PERIODS (OCT. 1973 TO OCT. 1974) AT GIND AND WND

Panel	GIND		WND	
	Immersion Period			
	6 months	12 months	6 months	12 months
Control (non-toxic)	631	1786	210	372
Paint A *	10	13.5	5.5	15.5
Paint B **	4	33.6	5	27.3

TABLE 13

SPECIES DIVERSITY INDICES (D') FOR THE FOULING ON CONTROL (NON-TOXIC) AND ANTIFOULING SURFACES IMMERSED FOR 6 AND 12 MONTH PERIODS (OCT. 1973 TO OCT. 1974) AT GIND AND WND

Panel	GIND		WND	
	Immersion Period			
	6 months	12 months	6 months	12 months
Control (non-toxic)	2.161	2.341	2.397	2.095
Paint A*	0.190	0.858	0.450	0.247
Paint B**	0.500	0.734	0.650	0.340

* 12.6% TBTF   ** 16-17% TBTF + Ametryne (3%).

Tables 14 and 15 list the species which settled on the antifouling surfaces at GIND and WND respectively.

TABLE 14

FOULING SPECIES RECORDED ON ANTIFOULING SURFACES AFTER 6 AND 12 MONTHS IMMERSION AT GIND

Panel Immersion Period	Paint A	Paint B
6 months	*Hydroides norvegica* *Balanus variegatus v. cirratus*	*Hydroides norvegica* *Balanus variegatus v. cirratus* *Spirorbis sp.* *Halocordyle distacha*
12 months	*Balanus variegatus v. cirratus* *Hydroides norvegica* *Bugula avicularia* *Bugula neritina* *Amphipods* *Spirorbis sp.* *Bowerbankia sp.* *Giffordia sp.*	*Balanus variegatus v. cirratus* *Hydroides norvegica* *Bugula avicularia* *Bugula neritina* *Amphipods* *Spirorbis sp.* *Balanus variegatus v. communis* *Unidentified Ascidian*

TABLE 15

FOULING SPECIES RECORDED ON ANTIFOULING SURFACES AFTER 6 AND 12 MONTHS IMMERSION AT WND

Panel Immersion Period	Paint A	Paint B
6 months	*Elminius modestus* *Balanus variegatus v. cirratus* *Amphipods* *Spionids*	*Elminius modestus* *Balanus variegatus v. cirratus* *Amphipods* *Spionids* *Ciona intestinalis*
12 months	*Elminius modestus* *Amphipods* *Spionids* *Balanus variegatus v. cirratus*	*Elminius modestus* *Balanus variegatus v. cirratus* *Spionids* *Amphipods*

B2. Microfouling Data

Table 7 lists the microfouling species recorded at WND. Microfouling studies were only carried out at WND because of limited access to GIND. The results of the three 'slide programs' carried out at WND during the project (February/March 1974, May 1974 and August/September 1974) are summarised in Tables 16 to 18.

The results in Tables 16-18 were used to plot Figs. 17-19 which represent the major changes in the 'primary slime' or microfouling assemblage between 2 hours and approximately 31 days immersion. Figs. 17a-e represent the February/March Slide Program, Figs. 18a-e the May Slide Program and Figs. 19a-e the August/September Slide Program. Figs. 17a, 18a and 19a are plots of percentage surface cover of slide versus immersion period in days. Figs. 17b, 18b and 19b are plots of diatoms/cm^2 on slide versus immersion period in days. Figs. 17c, 18c and 19c are plots of bacteria (millions)/cm^2 on slide versus immersion period in days (to approximately 10 days), Figs. 17d, 18d and 19d are plots of algal spores/cm^2 on slide versus immersion period in days. Finally, Figs. 17e, 18e and 19e are plots of Protozoa/cm^2 on slide versus immersion period in days.

Fig. 20 is a plot of diatoms/cm^2 on a glass slide after 16 days immersion versus month of immersion of slide (Feb/March, May, and August/September).

TABLE 16

FEBRUARY/MARCH SLIDE PROGRAM

Summary of the species which settled on non-toxic glass microscope slides immersed at WND for periods ranging from 2 hours to 29 days between 25/2/74 and 26/3/74

Immersion Period of Slide	2 hours	4 hours	1 day	2 days	3 days	4 days	8 days	10 days	16 days	18 days	22 days	29 days
% Surface Cover	0.2	0.4	0.4	0.5	0.5	0.6	2.5	5	45	70	90	70
Diatoms/cm^2	0	0	0	10	10	31	52	52	27,000	41,000	87,000	11,000
Bacteria/cm^2	0.3 million	0.4 million	1.2 million	1.3 million	2.0 million	4.3 million	3.5 million	2.7 million	-	-	-	-
Algal Spores/cm^2	0	0	0	0	0	10	115	95	645	760	1400	1450
Protozoa (*Vorticella* sp.)/cm^2	0	0	0	0	0	0	10	10	80	175	230	240
Dominant Diatom Species	-	-	-	No. 3	No. 3	No. 3	No. 1	No. 7	No. 1	No. 4	No. 17	No. 17
Barnacles (*Elminius*)	0	0	0	0	0	0	0	0	120	52	160	130
Serpulids	0	0	0	0	0	0	0	0	1	2	0	0
Amphipods	0	0	0	0	0	0	0	0	3	0	3	19
Ascidians	0	0	0	0	0	0	0	0	0	0	0	1

TABLE 17

MAY SLIDE PROGRAM

Summary of the species which settled on non-toxic, glass microscope slides immersed at WND for periods ranging from 2 hours to 31 days between 6/5/74 and 6/6/74

Immersion Period of Slide	2 hours	4 hours	1 day	2 days	3 days	4 days	7 days	9 days	14 days	16 days	18 days	21 days	23 days	25 days	31 days
% Surface Cover	0.1	0.1	0.2	0.4	0.5	0.6	2.0	5	10	12	20	25	35	45	75
Diatoms/cm^2	0	0	0	21	10	10	10	21	21	31	385	510	1490	6300	20000
Bacteria/cm^2	0.2 mil	0.4 mil	0.8 mil	1.0 mil	2.0 mil	2.8 mil	2.4 mil	1.8 mil	-	-	-	-	-	-	-
Algal Spores/cm^2	0	0	0	0	0	0	0	0	0	0	31	31	73	190	210
Protozoa *(Zoothamnion ?)*/cm^2	0	0	10	10	31	21	52	125	73	63	63	32	63	94	20
Dominant Diatom Species	-	-	-	No. 3	No. 3	No. 3	No. 3	No. 3	No. 3	No.31	No.31	No.31 + No.36	No.31 + No.36	No.31 + No.36	No. 31
Barnacles *(Elminius)*	0	0	0	0	0	0	0	0	0	0	0	0	0	3	64

TABLE 18

AUGUST/SEPTEMBER SLIDE PROGRAM

Summary of the species which settled on non-toxic, glass microscope slides immersed at WND for periods ranging from 2 hours to 36 days between 26/8/74 and 1/10/74

Immersion Period of Slide	2 hours	4 hours	1 day	2 days	3 days	4 days	9 days	11 days	14 days	17 days	21 days	24 days	28 days	30 days	36 days
% Surface Cover	0.1	0.1	0.2	0.2	0.3	0.5	4	5	8	15	25	40	55	75	80
Diatoms/cm^2	0	0	0	0	21	21	52	94	290	1560	2385	8125	15000	19000	17000
Bacteria/cm^2	0.2 mil	0.3 mil	0.9 mil	1.0 mil	1.9 mil	3.0 mil	2.3 mil	-	-	-	-	-	-	-	-
Algal Spores/cm^2	0	0	0	0	0	0	0	21	42	73	115	146	130	104	146
Protozoa (*Zoothamnion ?*)/cm^2	0	0	21	10	10	10	63	52	63	10	104	270	104	270	290
Dominant Diatom	-	-	-	-	No.3	No.3	No.3	No.3	No.3	No.36	No.36	No.31	No.31	No.13	No.31
Barnacles (*Elminius*)	0	0	0	0	0	0	0	0	0	2	33	135	122	212	120
Amphipods	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0
Serpulids	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

4. DISCUSSION

A. Hydrographic and Rainfall Data

Fig. 2 shows that the average surface water temperature at GIND is consistently higher that at WND throughout the year. The difference in average surface water temperatures in summer is approximately 2°C and in winter 4-5°C, the smallest difference occurring in November (1-2°C). The average surface water temperatures exceed 20°C for 6 months of the year at GIND compared with only 3 months at WND. These differences in surface water temperatures reflect the latitudinal difference of the two sites, GIND being located 4° North of WND.

Fig. 3 shows that the surface water temperatures from November 1973 to October 1974 have been slightly above average at both sites, which is indicative of a mild winter. However, although the study period has been mild, it has also been particularly wet. Fig. 3 also shows that the rainfall between November 1973 and September 1974 has been well above average at both sites. The average yearly rainfall for the WND area is 657 mm and 691 mm had already fallen between January, 1974 and mid-October 1974. Similarly the average yearly rainfall for the GIND area is 1204 mm and 1556 mm had already fallen between January 1974 and mid-October, 1974.

The above average rainfall has had marked effects on the surface water salinities (approximately related to chlorinity) at the two sites (Fig. 3). Consistently heavy rains in March at GIND reduced the surface water salinities to well below average and these remained low through March, April and May. Heavy rain occurred at WND during April and May and again during July causing large changes in surface water salinities at these times.

The hydrographic and rainfall data outlined above will be discussed later in relation to seasonal variations in fouling intensity at GIND and WND.

B. Fouling Data

As was indicated in the results, a large number of marine fouling species were recorded, encompassing a sizeable taxonomic range (13 phyla). Thirty-eight of seventy-one macrofouling species recorded occurred at both sites suggesting a large degree of similarity in the fouling fauna and flora at the two sites. However, as Table 8 shows, there is a significant difference in the dominant fouling species and thus the resultant fouling communities at the two sites. The major reason suggested for this observation is the difference in surface water temperatures at GIND and WND. The book 'Marine Fouling and It's Prevention' (1952) points out that "temperature appears to be the principal condition limiting the geographical distribution of marine animals, and determining their periods of breeding". Besides surface water temperature the slightly more estuarine situation of WND (Hobsons Bay) and variations in pollution levels at the two sites may be influential factors. These points are expanded upon further in the discussion of the Series (a), (b) and (c) panels.

B1. Macrofouling Data

Series (a) - Temporal Sequence/Succession Panels

As was mentioned in the results, the major aim of this series of panels was to monitor the temporal sequences of change in the fouling communities at GIND and WND over a 12 month period and to investigate the possibility of true biotic succession occurring at either or both sites. The classic definition of biotic succession comes from studies of terrestrial plant communities whereby one type of vegetation may modify or in some way prepare a situation favourable for a succeeding community of plants. In the case of marine fouling it must be determined whether the attachment and development of a particular fouling community modifies the substrate in such a way as to facilitate the attachment of the next group of fouling organisms. For instance the presence of a barnacle community may facilitate or may even be necessary for the attachment of an ascidian or mussel community.

Most of the studies carried out on biotic succession within developing fouling communities has concentrated on the relationship between the 'slime film' (microfouling i.e. marine bacteria, diatoms, protozoans etc.) and the subsequent fouling attachment (macrofouling). Phelps (1942) produced data which suggested that the presence of a slime film may favour the attachment of barnacles. However, Phelps also observed barnacles attaching to freshly exposed panels demonstrating that the slime film is not essential for their attachment. Millar (1946) similarly showed that the presence of a slime film facilitated but was not essential for the attachment of the erect bryozoan *Bugula neritina*. The experiments of Whedon (1937) gave results which suggested that the presence of a slime film facilitated the attachment of the ascidian *Ciona intestinalis* in agreement with the observations of Phelps (1942) and Miller (1946). Many other such studies have been carried out (Zobell and Allen (1935), Miller et al. (1948), Wood (1950)), a recent example of which is the work of Horbund and Freiberger (1970). All these studies suggest that the presence of a slime film modifies the substrate in such a way as to facilitate the attachment of the subsequent group of foulers and are thus well documented cases of successional changes within developing fouling communities.

Although a great deal of information is available on the relationship of the slime film to subsequent fouling attachment, monitoring of the successional changes in 'macro-fouling' communities over long periods of time has not been as extensively covered. The major reason for this probably lies in the fact that fouling communities cause serious problems on ships hulls, etc., even at immature stages (e.g. 12-18 months immersion) so that the practicality of fouling studies usually does not require descriptions of the long term successional changes within fouling communities (e.g. over 2-4 years). However such 'long term' studies make possible the collection of valuable data pertaining to successional theory since the changes observed are usually rapid (relative to terrestrial plant successions), climax communities often being attained within 3-4 years.

Such studies monitoring the temporal sequences of change of fouling communities on long term immersion panels can, however, be fraught with difficulty. On a newly exposed surface micro-organisms appear first, and

multiply rapidly. These are then replaced by the more rapidly developing macro-organisms which cover the surface, only to be replaced by more slowly developing forms which crowd out the first-comers. This 'crowding out' process of the rapidly developing macrofoulers by the slower growing forms is a definite change in the structure of the fouling community with time but is not a true successional change and should not be mistaken as such. A chance of this sort must be recognised merely as a "temporal sequence" (the inverted commas signifying usage in this strict sense) in the development of the community. Also the sequence in which organisms appear in the fouling community is influenced by the time of year at which the panel is immersed since different species have different seasons of breeding and attachment. These "seasonal sequences" may cause changes in the structure of the fouling community with time but once again are not true successional changes and once again should not be mistaken as such. Distinguishing the "temporal" and "seasonal" sequences of change from true "biotic successional" changes within fouling communities over long periods of time may be difficult.

With "temporal" and "seasonal" influences having marked effects on the structure of the fouling community, the book 'Marine Fouling and It's Prevention' (1952) concludes "most well documented cases of true biotic succession in marine fouling communities come from tropical waters where seasonal phenomena are less pronounced. Where seasonal variations are large biotic succession may not be obvious".

GIND and WND are both situated at temperate latitudes and as Fig. 2 has indicated seasonal variations in the surface water temperatures at both sites are marked. It is in the interests of the discussion here to foreshadow the discussion of the series (b) and (c) panels by indicating that distinct seasonal variations in fouling intensity occur at both sites (see Figs. 12 and 13). With this fact in mind the observed sequences of change in the fouling communities at GIND and WND over 12 months (Figs. 6 and 7) were examined and the following question was posed :

"Do these observed changes in community structure at GIND and WND modify the substrate in such a way as to facilitate the subsequent attachment of the next group of foulers, thus constituting TRUE SUCCESSIONAL CHANGES or are they merely an expression of (a) slower developing forms gradually crowding out the first comers ("TEMPORAL" SEQUENCES) or (b) individual species adding to and modifying the community by settling in their season of attachment (SEASONAL SEQUENCES), thereby constituting community changes within but relatively independent of the overall biotic succession?"

(1) <u>Garden Island Naval Dockyard</u>

Figs. 4a and 6 indicate that GIND is a much more intense fouling site than WND. The dry and wet weights of fouling at GIND are consistently higher than at WND for similar immersion periods. Fig. 4a suggests that the fouling dry weight ratios per unit area (GIND : WND) are approximately 2.5:1 after 3 months immersion, 4:1 after 6 months immersion, almost 5:1 after 9 months immersion and approximately 6-7:1 after a 12 month immersion period. Fig. 4a also shows that at GIND the increases in dry weight over the 12 month study period occurred in 3 main phases - 0-3 months, 3-9 months

and 9-12 months. As was indicated in the results these 3 major phases of increase could be related to specific changes in the structure of the fouling community (Fig. 6). The initial increases in dry weight (0-5 months) was due to the heavy deposition and fast growth of the serpulid *Hydroides norvegica*. The second phase (3-9 months) correlated with the gradual increase in significance of the barnacle *Balanus variegatus v. cirratus* to its dominant position at 9 months immersion. The final phase (9-12 months) was due to the heavy growth and some further deposition of the solitary ascidian *Pyura stolonifera* upon the barnacles. These changes in community structure will now be examined in relation to the question previously posed concerning biotic succession.

It is quite likely that a marine slime covered the panels initially, possibly facilitating the attachment of the serpulids. No method of testing this assumption was attempted in this project. However, serpulids averaging 1 cm in length were observed on the panels after 30 days immersion, along with small barnacles and algae. The large build up in dry weight of fouling between 0 and 3 months did not involve any large qualitative community changes. It simply reflected the fast growth of *Hydroides norvegica*. One change in the community structure was however noteworthy, that being the decreased significance of algae (*Ulva lactuca* and *Enteromorpha intestinalis*) between 20 days and 3 months immersion. This trend was extended until, after 6 months immersion, the algae were insignificant as foulers. These observations are interesting in the light of those of Margalef (1962) who stresses "as succession proceeds ...... the surface colonised by animals in relation to that colonised by algae increases". In the case of GIND, the algae have almost disappeared from the fouling community due to the robust mechanical action caused by the rapid growth of *Hydroides norvegica* possibly nipping off the algal strands at their base, a process quite likely to be termed a "temporal sequence" rather than a true "successional change".

The second major change in the structure of the fouling community at GIND was the increase in significance of *Balanus variegatus v. cirratus* in relation to *Hydroides norvegica* between 3 and 9 months immersion. As mentioned in the results, and indicated in Fig. 5b, the numbers of *Balanus* did not increase greatly between 3 and 9 months. However, the average basal diameter and also the average height/diameter ratio of these barnacles did increase a great deal. This suggests that the increased dominance of *Balanus variegatus v. cirratus* and the associated decrease in significance of *Hydroides norvegica* was due mainly to the growth of the barnacle. This slower but more robust growth of the *Balanus* seemed to "squeeze" the *Hydroides* tubes, crushing them and eventually over-growing them. When large parts of the fouling were removed from the 6 or 9 month panels, a layer of crushed white serpulid tubes was always obvious within the crevices that remained between the large barnacles. This change in the structure of the fouling community thus represents a case of a "slower growing form gradually crowding out the first-comers" i.e. a "temporal sequence" of change. The presence of a dense coverage of *Hydroides norvegica* did not in anyway facilitate the attachment and growth of the *Balanus variegatus v. cirratus*. In fact, it seems that both these species settled in heavy concentrations very early in the immersion period (0-3 months). Different growth rates of the two species has been the cause of the changes in the fouling community between 0 and 9 months immersion.

The changes occurring in the fouling community during the final phase (9-12 months immersion) pose more interesting problems than the previous two phases of change described. The individuals of *Pyura stolonifera* actually settled *upon* the *Balanus variegatus v. cirratus* layer (which was dead at this stage probably due to natural causes i.e. *Balanus* had reached the end of its normal life span). The question arises: does the presence of a dense community of dead barnacles (*Balanus variegatus v. cirratus*) after 6-9 months immersion *facilitate* the attachment of *Pyura stolonifera* or would the *Pyura's* have settled on a panel simply covered with a dense layer of *Hydroides norvegica* tubes?

In answer to this question it can be pointed out that individuals of *Pyura stolonifera* have been observed settling directly onto a heavy tubeworm coverage (e.g. Panel 31, Panel 15) so that dense barnacle coverage is not necessary for the subsequent attachment of *Pyura*, and probably does not facilitate the attachment of this ascidian any more than a tubeworm coverage.

An extension of this reasoning poses the question as to whether the *Pyura stolonifera* require a reasonably heavy fouling coverage before they attach. Firstly, no *Pyura stolonifera* were observed to settle on monthly immersion panels throughout the year. Secondly panels Z and Z10 (monthly immersions) and 32 (2 months immersion) were immersed during the period of the *Pyura stolonifera* "build up" between 9 and 12 months immersion of the series (a) panels and no individuals of *Pyura stolonifera* were observed to settle on Z, Z10 or 3Z. Furthermore individuals of *Pyura stolonifera* have only been observed to settle on panels immersed for periods in excess of 3 months. Only small numbers of this species were recorded on the 3 month immersion panel with much greater numbers occurring at 6 and 9 months immersion with the number actually levelling out after 12 months immersion. All this evidence suggests that *Pyura stolonifera* does require the presence of reasonably heavy fouling on a surface before it settles i.e. it requires the surface to be modified on some way by other organisms before it can settle.

Another factor complicating this issue is that the settling season of *Pyura stolonifera* as determined by Wood and Allan (1958) is spring, a period corresponding closely to the 9-12 months immersion period of the series (a) panels. However, as mentioned above, most of the increased dominance of *Pyura stolonifera* was not so much due to a large increase in numbers as much as a large increase in the size of the individuals already present. The individuals of *Pyura stolonifera* actually settled on the panels between 3 and 9 months immersion, but were only represented by small to medium sized individuals and therefore did not rival the barnacles for dominance of the panel at the 6 and 9 month stages. The acceleration of growth and subsequent attainment of dominance of *Pyura stolonifera* between 9 and 19 months was probably triggered by the increase in surface water temperatures at the beginning of spring. The fact that the *Pyura stolonifera* appeared to settle between 3 and 9 months immersion (February to July) appears to eliminate the possibility that the deposition of *Pyura stolonifera* was solely a reflection of a seasonal sequence of change.

A final point relevant to the discussion is the fact that *Pyura stolonifera* is the well known "cunjevoi" which forms climax communities around low water mark in the Sydney Harbour region.

In conclusion it is suspected that the ascidian *Pyura stolonifera* may require the presence of a reasonable fouling coverage before it can settle. This coverage could either be a tubeworm or barnacle coverage, although barnacles, particularly dead ones, may facilitate attachment more than a tubeworm coverage. Thus the heavy fouling build up leading to the attachment of *Pyura stolonifera* is a successional change because it modifies the substrate in such a way as to lead to the attachment of the next group of foulers. However, the initial "takeover" of algae by *Hydroides norvegica*, the more gradual "takeover" of *Hydroides norvegica* by *Balanus variegatus v. cirratus* between 3 and 9 months and for that matter the growth of *Pyura stolonifera* over the dead barnacle coverage between 9 and 12 months probably represent "temporal sequence" changes and may be incidental to the overall direction of the biotic succession. If the *Pyura stolonifera* does in fact represent a climax community for this area, the growth of these ascidians between 9 and 12 months would represent an attainment of such a climax and then of course, could not be considered incidental to the overall succession.

This last point concerning climax fouling communities at GIND deserves a little more discussion. Many studies of the long term changes in fouling communities at temperate sites generally recognise mussels (*Mytilus* sp.) as the climax community, these often taking over from ascidians. Individuals of *Mytilus planulatus* occur in dense clumps on the wharf piles near the raft and although the observation concerning "cunjevoi" (*Pyura stolonifera*) forming climax communities at low water mark appears to complicate the issue it is possible that stands of *Mytilus planulatus* may represent a true climax community at GIND.

One criticism which could be levelled at a study such as that described above is that panels immersed at different times of the year may display completely different sequences of change in their fouling communities and may in fact support very different fouling communities after a 12 month immersion period. It is the opinion of this writer, however, that such a criticism is not critical at such temperate and highly seasonal sites as GIND and particularly WND. For instance if a set of panels had been immersed at GIND in late autumn/early winter instead of mid-October, very little would have settled on the panels until October/ November anyway (see Fig. 9). The only slight difference could be that the *Balanus variegatus v. cirratus* which begin to settle slightly earlier than the *Hydroides norvegica* may have achieved a month's growth before any *Hydroides* tubes had attached. This would probably shorten the "squeezing out" process of *Hydroides norvegica* by *Balanus variegatus v. cirratus* but the resultant fouling community after 12 months immersion would quite likely be very similar to the one observed after 12 months immersion in this project.

The main point to be drawn from this discussion is that it is particularly difficult to distinguish "temporal" and "seasonal" sequences of change from true biotic successional changes within fouling communities over a 12 month period at temperate sites such as GIND.

(2) Williamstown Naval Dockyard

Figs. 4a and b show that the changes in dry and wet weights of fouling at WND over a 12 month period differ considerably from those observed at GIND. There was a similar build up of fouling in the first 3 months but between 3 and 6 months immersion a decrease in fouling weights was recorded followed by a gradual increase in these values between 6 and 12 months immersion. As seen in Figs. 4a and b the dry and wet weights of fouling after 12 months immersion (October 1973 to October 1974) are actually less than those recorded after 3 months immersion. However, as indicated in the results the fouling after 3 months immersion was loosely attached compared with the fouling after 12 months immersion. Once again the changes in dry weights of fouling noted in Fig. 4a for WND can be related to significant changes in the structure of the fouling community over a 12 month immersion period (Fig. 7).

The first major change in community structure after the initial attachment and growth of the *Elminius modestus* layer was the settlement and subsequent growth of spionids and to a lesser extent ascidians upon this barnacle layer. The first question raised by this observation is whether the presence of an *Elminius modestus* layer modifies the substrate in such a way as to facilitate the subsequent attachment of spionids and ascidians. Firstly, whenever spionids were observed to settle on monthly immersion panels they were often clustered in the crevices created by the protruding identification letters and numbers of the panel or near the edges of barnacles. Spionids rarely settled on bare, flat surfaces. This supports that the *Elminius modestus* layer did facilitate the attachment of spionids between 1 and 3 months thereby representing a successional change. Secondly, the important ascidians after 3 months immersion were *Ciona intestinalis, Pyura stolonifera* and *Botryllus schlosseri*. It has previously been suggested that the presence of a heavy fouling layer may facilitate the attachment of *Pyura stolonifera* at GIND and it is possible that this is also the case for the ascidians observed to have settled after 3 months immersion at WND.

In the light of these suggestions made above, the mass "fall off" of the *Elminius modestus* underlayer and its accompanying upper layer of spionids and ascidians (which presumably caused the death of the *Elminius modestus* by disrupting their feeding mechanism) appears to be rather unusual. Nevertheless the evidence for such a "fall off" process is very strong after 3 months immersion.

Furthermore, after 6 months immersion large spionids and ascidians were rare in the fouling community and most of the *Elminius modestus* present on this panel were small, newly established individuals which had settled on the many bare areas of the panel. This suggests that the "fall off" process continued until the originally established *Elminius modestus* underlayer plus its accompanying upper layer of heavy fouling had been displaced from the panel.

Dr. Nick Holmes (Marine Pollution Section, Victorian Fisheries and Wildlife Department) who is in charge of the marine fouling studies in Hobsons Bay has suggested that the mass "fall off" of spionids and ascidians described above may well be a natural process. He has further pointed out

that many of the ascidians may die and fall off panels with the decline in surface water temperatures during autumn and winter (Holmes, personal communication).

Unfortunately it became necessary to change the location of the panels along Nelson Pier after 3 months immersion. This relocation was carried out by divers and although assurance was given that the panels remained immersed at all times during the operation it was still difficult to determine the extent to which this disturbance may have caused any death and "fall off" of fouling from the panels. Nevertheless this does not in any way alter the evidence of "fall off" of fouling on the 3 month immersion panel and it is stressed that Dr. Holmes was aware of the relocation of the panels when he expressed his opinion.

The fouling on the 6 month immersion panel was dominated by the barnacle *Balanus variegatus v. cirratus* and to a lesser extent by the serpulid *Mercierella enigmatica*. The barnacles present had settled mostly between 3 and 6 months immersion (175 *Balanus* were recorded after 3 months immersion and 1155 after 6 months immersion) and very few *Balanus* were dead at the 6 month stage (20%). This heavy settlement of *Balanus variegatus v. cirratus* between 3 and 6 months immersion probably occurred directly onto the many bare areas of the panel created by the fouling "fall off" described above. The settlement of *Balanus* is therefore a little difficult to fit into an overall successional process. It may be a little presumptuous to suggest that the overgrowth of *Elminius modestus* by spionids and the fouling "fall off" and subsequent creation of bare patches facilitates the attachment of *Balanus variegatus v. cirratus*, for example.

The structure of the fouling community did not change significantly between 6 and 12 months immersion. The barnacle *Balanus variegatus v. cirratus* became more dominant due mostly to the growth of individuals already present on the panels after 6 months immersion. This change was similar to that observed to occur at GIND between 3 and 9 months immersion although, as mentioned in the results, the *Balanus* at WND did not reach anywhere near the crowded conditions attained at GIND. The increase in significance of ascidians by 12 months immersion (Fig. 7) appears very similar to the change observed at GIND between 9 and 12 months immersion (Fig. 6). However the ascidians on the 12 month immersion panel at WND were colonial encrusting forms (*Botryllus schlossari*, *Botrylloides leachii* and a species of the sub-family Polyclininae) as opposed to the solitary, erect forms dominant at GIND after 12 months. In view of this it could be suggested that the fouling community observed at WND after 12 months has simply attained the "barnacle stage" and may not have reached the "maturity" of the fouling community observed at GIND after a similar immersion period.

Observations of what are considered to be mature fouling communities at WND are relevant to this last point. Surfaces immersed a few metres below the water line at WND generally support a fouling community dominated by the solitary ascidian *Ciona intestinalis* after approximately 2-3 years immersion. These ascidians occur in high densities and attain large dimensions (e.g. 15-20 cm in length). This stage could be termed the "ascidian stage" and is possibly equivalent to the *Pyura stolonifera* "ascidian stage" observed at GIND after 12 months immersion.

Associated with the *Ciona intestinalis* and often near the water mark are mussels, *Mytilus planulatus*. It is likely that the climax fouling community at WND is one dominated by mussels which may move down and gradually take over from the *Ciona intestinalis* possibly after 3-4 years immersion. Such speculation is supported by the work of Scheer (1945) who studied the development of marine fouling communities at Newport Harbour, California. Scheer considered the mussel *Mytilus* represented a climax community for the area. He also noted that mussels were observed to settle only on surfaces bearing a bryozoan, *Ciona or Styela* (another solitary ascidian) community. This work is particularly relevant when it is considered that variations in surface water temperature at Newport Harbour are almost identical to those occurring at WND. The work of Scheer is also of great interest because it represents one of the few well documented descriptions of the successional processes occurring in the fouling communities of a temperate site, right through to the development of the climax community.

Finally, Fig. 8 compares the changes in species diversity of the fouling communities over a 12 month immersion period at GIND and WND. The diversity at both sites levels out at approximately the 6 month immersion stage after an initial rise. This, of course, disagrees with classic successional theory as stated by Margalef (1962): "as succession proceeds, the community becomes more complex", but this disagreement is solely due to the limitation placed on the calculation of the species diversity index as pointed out in the results.

In conclusion it can be stated that distinguishing "temporal" and "seasonal" sequences of change from true biotic successional changes within the fouling communities at WND over a 12 month period was even more difficult than distinguishing such changes at GIND and further long term exposure trials are required at both sites. *It is fairly obvious that* all the observed changes in the structure of the fouling communities at GIND and WND over a period of 12 months immersion are not necessarily true biotic successional changes. Some are in fact independent of the overall successional process. A clearer picture could possibly be gained by immersing panels for up to 3 years at each site. A further fruitful continuation of such studies would be a comparison of GIND and WND with a tropical fouling site where seasonal sequences of settlement of the fouling organisms may be less pronounced.

Series (b) - Seasonal Variations in Fouling Intensity: Monthly Immersion Panels

As mentioned previously, the major aim of this series of panels was to determine any seasonal variations in fouling intensity at GIND and WND and to determine the seasons of settlement of the common fouling species. Figs. 9 and 10 indicate that seasonal variations in fouling intensity are marked at both sites. Comparison of these graphs with Fig. 2 further indicates that the season of maximum fouling intensity corresponds with the season of maximum surface water temperatures at both sites. This situation is typical of temperate fouling sites, and is mainly due to the fact that the variations in surface water temperatures generally restrict the breeding seasons of most marine fouling organisms to the warmer months. The book 'Marine Fouling It's Prevention' (1952) points out that "in regions where marked seasonal changes in temperature occur, the

reproduction and growth of many organisms are completely suppressed in the winter period". The result is that at temperate sites most fouling organisms attach at some limited and definite portion of the year. The onset of warmer surface waters in spring generally stimulates the growth and production of the gonads and gametes of fouling species and may also lead to increased metabolic and growth rates of the organisms concerned. The period between onset of gonadal development and the production and release of gametes or larvae varies from species to species but usually the time involved ensures that the larvae are released into an environment favourable for their survival and development to the settling stage, this usually occurring in the summer months when surface water temperatures are at a maximum. However, not only the period between onset of gonadal development and gamete or larval release but also the onset of gonadal development itself varies from species to species so that settling seasons of individual species can vary considerably. Settling seasons of individual fouling species at GIND and WND will be discussed later.

Of particular interest on a comparative basis are Figs. 9 and 10. Several important points are to be noted from these graphs. Firstly, GIND appears to be a much more intense fouling site, in season, than WND. Around February/March the ratio of fouling attachment on a dry weight basis per unit area per month is approximately 10:1 in favour of GIND. However, as Fig. 9 suggests, the dry weights of fouling per unit area per month at the two sites do not differ greatly between April and November, with GIND again having slightly greater dry weights of fouling. Secondly the season of maximum fouling settlement appears to be longer at GIND than at WND. Figs. 9 and 10 suggest that the settling season at GIND extends through December, January, February and March. However the writer favours a principal settling season from November to April at GIND for the following reasons. Extremely heavy rainfall was recorded in March at GIND, severely reducing the surface water salinity at the raft site in March and April. The reduced salinities, particularly in March could well have reduced the supply of available larvae by affecting the adult organisms as well as the larvae themselves causing an abnormally reduced settlement of fouling species in April (Panel S5). And again, rainfall in October 1973 at GIND was almost three times the average causing severe reduction of surface water salinities in October and November and again possibly leading to reduced fouling settlement.

The season of maximum fouling settlement at WND appears to extend through January, February and possibly into March (Figs. 9 and 10). This reduction of the settling season at WND compared with GIND can be correlated with the reduced duration of warm (e.g. greater than 20°C) surface water temperatures. This observation agrees well with the opinion expressed by the book 'Marine Fouling and It's Prevention' (1952): "the duration of the breeding season is determined by the time during which temperatures remain above the critical level for reproduction. Within the range for any species this period is narrowed as the latitude increases, until at some point the species cannot maintain itself".

The third and final point to be drawn from Figs. 9 and 10 is that the seasonal variations in fouling intensity are actually greater at GIND than WND. At GIND a variation between 40-50 grams and 0.6 grams dry weight of fouling per month on a 30 cm x 15 cm PVC panel was recorded compared with a variation of only 4.0 to 0.3 grams at WND.

In summary the seasonal fluctuations in surface water temperature at GIND and WND are suggested as the main causal factor of the seasonal variations in fouling intensity at the two sites. The warmer surface water temperatures at GIND probably determine to a large extent the longer and more intense fouling season at this site compared with WND. Besides surface water temperatures, surface water salinities are also seen to have an affect on the seasonal fouling intensity but not to anywhere near the extent of surface water temperatures. Variations in surface water salinity may be more important at WND in the more estuarine environment of Hobsons Bay.

Fig. 11 is a plot of the Species Diversity Index (D') of fouling communities on monthly immersion panels at both sites versus month of immersion of panel. The changes in D' throughout the year seem to follow almost opposite trends at the two sites. At GIND, the species diversity within fouling communities in spring and summer appears to be lower than in the autumn and winter. The reason for this is that the communities in spring and summer are often dominated with huge numbers of one or a few species e.g. *Hydroides norvegica*. Many species are present but the numbers of individuals within the community are large. In autumn and winter the numbers of individuals within the fouling communities decrease markedly but a high percentage of the fouling species still settle in small numbers so that the diversity is large. On the other hand, the diversity of species in the fouling communities at WND throughout the year peaks in summer and early autumn when many species are settling but none in numbers so great as to completely dominate the community. In winter, the surface water temperatures become so low that only a few species are capable of settling (e.g. *Elminius modestus, Cryptosula* sp. along with a "mat" of the filamentous colonial diatoms *Melosira* sp. and *Navicula* sp.) and these sometimes may settle in reasonable numbers. Thus the diversity of the species constituting the winter fouling communities at WND is very small. The reason for this difference in the fouling communities at GIND and WND once again probably lies in the fact that the surface water temperatures, particularly in winter, are consistently higher at GIND. The winter surface water temperatures at GIND (which are 4-5°C greater than those at WND - Fig. 2) are probably sufficient to allow small amounts of breeding and settlement of many of the fouling species whilst those at WND are too low to permit such breeding.

Figs. 12 and 13 summarise the probable seasons of settlement of the principal marine fouling organisms at GIND and WND as determined from data collected in this 12 month study. However, it must be stressed from the outset that these histograms represent only estimates of the settling seasons since the study period was so short. Most studies of this kind aimed at determining the settling seasons of particular fouling species are carried out over many years, e.g. Wisely (1959) studied Sydney Harbour over a 10 year period and Coe and Allen (1937) continued their studies at the Scripps Institute of Oceanography for 9 years. Nevertheless, the data presented for WND probably represent the first ever records for this Naval Dockyard and the GIND date agree fairly well, in most cases, with that of Wisely (1959).

Fig. 12 represents the WND records. The small barnacle *Elminius modestus* settles throughout the whole year at WND with an apparent major settling season in the spring. The only other animal species to settle almost throughout the year is the encrusting bryozoan *Cryptosula* sp. All the other animal foulers and most of the algal ones show a distinct lack of settling activity during the winter months. This decrease in settling activity during autumn and complete lack of such activity in winter is typified by the tube-forming amphipods. These crustaceans have a peak settling period corresponding to the months of warmest surface water (January and February) as do the spionids, *Bugula neritina* and *Ciona intestinalis*. Many species do however have peak settlement periods in late summer/early autumn such as the colonial ascidian *Botryllus Schlosseri*, the barnacle *Balanus variegatus v. cirratus*, the bryozoan *Bugula Stolonifera* and the serpulids *Mercierella enigmatica* and *Hydroides norvegica* while *Spirorbis* sp. actually has its peak settlement period in mid-autumn. Of the algae only *Enteromorpha intestinalis* displays settling activity throughout most of the year with an apparent peak settlement in mid-summer. *Ulva lactuca, Bryopsis plumosa* and *Polysiphonia* sp. also show peak settling activity in mid- to late summer. *Medeiothamnion protensum*, another species settling in summer, also appears to be capable of settlement in early autumn whilst *Dictyota dichotoma* shows a peak settlement in autumn.

Fig. 13 represents the GIND records. A comparison of these histograms with the ones for WND highlights the fact that most of the common fouling organisms at GIND have the potential to settle all the year or almost all of the year round whereas the settlement of those species common at WND is generally restricted to the warmer months of the year. The two most common fouling species at GIND, *Hydroides norvegica* and *Balanus variegatus* v. *cirratus* both settle throughout the year with *Hydroides* showing peak settlement in mid-summer whilst the major settlement period of *Balanus* extends from October to April. The bryozoan *Zoobotryon pellucidus* and the hydroid *Halocordyle distacha* appear to be the only two species which have their settling periods restricted to mid-summer. Most other species show distinct autumn settlement (*Spirorbis* sp., *Balanus variegatus* v. *communus* and *Schizoporella unicornis* or spring settlement (*Bugula neritina, Cryptosula* sp. and *Botryllus schlosseri*. The erect bryozoan *Bugula avicularia* has a very long settling season similar to *Balanus variegatus v. cirratus* and extends from July through to April. The encrusting bryozoan *Watersipora subovoidea* is the only species with a peak settlement period in winter. The algae *Enteromorpha intestinalis* and *Dictyota dichotoma* appear to settle mostly in the spring, *Ulva lactuca* and *Polysiphonia* sp. mainly in mid-summer and *Ceramium* sp. mainly in late autumn.

Figs. 12 and 13 also provide comparisons of the settling seasons of individual species at both sites. At WND the serpulid *Hydroides norvegica* and the barnacle *Balanus variegatus v. cirratus* both appear to settle in late summer to early autumn, that is, slightly later than at GIND. The erect bryozoan *Bugula neritina* has a much more restricted settling period at WND than at GIND. This species only settles in mid-summer at WND whereas settlement throughout the year is common at GIND, with an apparent peak in spring. *Cryptosula* sp. and *Botryllus schlosseri* both settle principally in the summer months at WND compared with a spring settlement

period at GIND. *Spirorbis* sp. settles in late summer to early autumn at WND compared with a mid autumn - early winter settlement at GIND. Similarly, *Enteromorpha intestinalis* has a distinct summer settlement period at WND compared with a spring settlement at GIND whilst the settling season of *Ulva lactuca* is extended more into early autumn at GIND than at WND. In general the settling seasons of individual species appear to be restricted more to the warmer months at WND than at GIND.

Series (c) - Seasonal Variations in Fouling Intensity: 3 Monthly Immersion Panels

As mentioned in the results the major aim of this series of panels was to determine any seasonal variations in fouling intensity at GIND and WND and to determine the seasons of settlement of fouling species which do not normally settle on monthly immersion panels. Figs. 14a and b once again indicate that seasonal variations in fouling intensity are marked and that the season of maximum fouling intensity corresponds with the period of maximum surface water temperatures. Fig. 15 shows exactly the same trends in species diversity of fouling communities as Fig. 11 and does not require any further discussion. Finally Figs. 16a to d show the major settlement period of two common fouling species at each site which occur infrequently on monthly immersion panels. *Galeolaria caespitosa* has an apparent peak settlement period between April and July (Fig. 16a) at GIND whereas *Pyura stolonifera* appears to settle principally between October and January (Fig. 16b). On the other hand *Pyura stolonifera* seems to favour January to April for settlement at WND (Fig. 16d) whilst the serpulid *Merclerella enigmatica* shows peak settlement between October and January (Fig. 16c).

Series (d) - Antifouling Panels

As previously mentioned, this panel series aimed to compare the performance of two advanced antifouling systems with the non-toxic controls of the series (a), (b) and (c) panels. Although Tables 11 and 12 suggest that the two antifouling systems tested compared favourably with the controls it must be pointed out that even as early as 6 months after immersion both systems were beginning to fail and would have been considered as failures between 6 and 9 months immersion. However this early failure was probably not due to inferior antifouling performance but rather to inferior application of the aluminium anticorrosive undercoat. Corrosion bubbles were obvious on all panels after only 6 months immersion which would be completely unsatisfactory in any evaluation of a new antifouling system. With the limitation to this trial just mentioned in mind, a re-examination of Tables 11 and 12 at least hints at the antifouling effectiveness possible from active ingredients such as Tri-butyl tin compounds.

An interesting point from Tables 11 and 12 is that Paint B, although outperforming Paint A after 6 months immersion, is actually inferior to it after 12 months immersion, despite the fact that the Paint B initially contained more of the toxic component. This possibly could have been due to the toxic in the Paint B system leaching out very quickly, thus giving reasonable performance up to 6 months but poor performance afterwards. The toxic in the Paint A system seems to have leached out in a more regular fashion thus affording it with superior antifouling properties between 6 and 12 months immersion.

Table 13 clearly indicates that the diversity of species making up the fouling communities on the antifouling panels is much less than that for the fouling communities on the non-toxic controls. Although the species that actually did settle on the antifouling panels are listed in Tables 14 and 15 it is difficult to make any comments as to the relative resistance to TBTF of the individual species because of the early failure of the anticorrosive undercoat. Most of the early settlers were prone to be found in corrosion pits. However it is interesting to note that a distinct mat of the brown algae *Giffordia* sp. had settled on the Paint A panel at GIND after 12 months immersion (Table 14) whereas no such mat occurred on the Paint B panel which contained the algicide Ametryne.

B2. Microfouling Studies

Tables 7, 16, 17 and 18 show that the microfouling or 'primary slime' which settles at WND is composed principally of diatoms, bacteria, algal spores and protozoa. All these components, particularly diatoms and algal spores display seasonal variations in their intensity of settlement. This can be seen by comparing Figs. 17a to 17e with Figs. 18a to 18e and 19a to 19e. Diatoms and algal spores settled in large numbers on the glass slide surfaces in February/March resulting in a rapid build up in surface area coverage (Fig. 17a) compared with the slower build up in May (Fig. 18a) and August/September (Fig. 19a). The decrease in diatom and overall surface cover in Figs. 17a, 17b and 19b is possibly due to a grazing effect. Initial coverage of the slide by bacteria (mainly gram negative rods approximately 1 micron in length) occurred in each slide program, with large concentrations being recorded even after only 2 hours immersion (Figs. 17c, 18c and 19c). The decline in bacterial concentrations between 4 and 10 days immersion in these latter figures is attributed to the increase in the protozoan populations (2 Ciliate species and a Suctorian - Figs. 17e, 18e and 19e) which presumably prey on the bacteria. The decline in bacterial concentration in relation to the increase in the protozoan population is particularly well illustrated in Figs. 18c and 18e. The fluctuations in the protozoan populations in May (Fig. 18e) and August/September (Fig. 19e) may be in response to some predator/prey relationship although no experiments to confirm or deny this hypothesis were attempted in this project.

The seasonal variation in the deposition of diatoms on glass microscope slides is clearly illustrated in Fig. 20. Similar graphs for algal spore and bacterial concentration and percentage surface cover could have been constructed. Nevertheless two significant points are obvious. Firstly, after 10 to 20 days immersion, 'primary slimes' at WND are dominated with diatoms (and to a lesser extent by algal spores). Bacteria although important in the early immersion stages in no way rival the diatomaceous component in terms of 'bulk' in the later stages of immersion. Secondly, seasonal variations in the intensity of deposition of the 'primary slime' do occur at WND. Once again the peak settlement period corresponds with the season of maximum surface water temperatures. The overall qualitative composition of this slime, however, does not vary significantly with season.

Of interest to the discussion concerning the presence of a 'primary slime' facilitating the subsequent attachment of macrofouling organisms is the observation that individuals of the barnacle *Elminius modestus* only settled on glass slides covered with a heavy diatomaceous film. In this case it appears that the 'primary slime' may well facilitate the attachment of this species of barnacle.

A Comparison of GIND with WND: Its Relation to the Proposed Newport D Powerstation

It has been shown in this report that GIND is a more intense fouling site in season than WND by a factor of somewhere between 5 and 10 times (dry weight per unit area per unit time basis) and the major reason suggested for this finding is the consistently higher surface water temperatures occurring at GIND. It was also pointed out that this difference was 1-2°C in summer and 4-5°C in winter. It is particularly tempting to suggest that with the advent of Newport D the 1-2°C increase in surface water temperatures expected in Hobsons Bay may increase the fouling on wharf piles and beacons to somewhere near the levels encountered at GIND. However, it is the opinion of this writer that such an occurrence is unlikely.

The reasoning behind this opinion is as follows. It must be remembered that Sydney Harbour is recognised as one of the most intense fouling sites in the world rated only behind such tropical sites as Kaneohoe Bay in Hawaii and Madras in India. It is certainly one of the heaviest fouling sites in the world *for its latitude*. For instance it has been shown at Materials Research Laboratories that GIND (Latitude 33°52'S) is in actual fact a more intense fouling site for 5-6 months of the year than is Clump Point, in North Queensland (Latitude 17°51'S). It thus seems unlikely that surface water temperatures alone are responsible for such intense fouling. Heavy nutrient inputs intc Sydney Harbour, possibly from sewage outlets, are suggested as a probable additional factor causing the intense fouling although no data comparing the nutrient inputs into Sydney Harbour and Hobsons Bay are presently available. High levels of solar radiation resulting in increased photosynthesis and thus greater food supply for filter feeders and 'catchers' (e.g. barnacles) are unlikely to be an important causal factor in the high fouling levels at GIND since a greater amount of solar radiation per annum is received at Clump Point. Finally it must be stressed that the benthic and littoral fauna of the Sydney Harbour region is exceedingly rich (Whitelegge as early as 1889 had recorded 2136 invertebrate species) so that an enormous variety of potential fouling species are present.

Therefore levels of fouling intensity *similar to* those encountered at GIND are unlikely to occur within Hobsons Bay when (and if) the Newport D power station becomes operative. Nevertheless, a slight enrichment of the fouling communities in Hobsons Bay is possible, in the form of lengthened settling seasons of common species and possible appearance of new fouling species.

5. CONCLUSIONS

1. Of 71 macrofouling species recorded in this project, 38 occurred at both GIND and WND. Despite the similar species lists, the dominant fouling organisms and therefore the overall fouling communities at the two sites differ markedly.

2. During a 12 month immersion period of non-toxic panels many changes in the structure of the fouling communities at both GIND and WND occurred. At both sites it was difficult to distinguish more "temporal" and "seasonal" sequences of change from true biotic successional changes. It is suggested that after 12 months immersion the fouling community that had developed at GIND had attained a more mature successional stage than the community developed at WND during a similar immersion period.

3. Seasonal variations in fouling intensity occur at both GIND and WND. The major fouling season at GIND is longer than that at WND and occurs during December, January, February and March but may extend from November to April. The major fouling season at WND is restricted to January, February and possibly March.

4. The major fouling season at both GIND and WND corresponds with the season of maximum surface water temperatures at the two sites.

5. GIND is a much more severe fouling site, particularly in the principal settling season, than is WND. Thus the fouling accumulated per unit area over a 12 month immersion period at GIND is far greater than that at WND. The data suggest that the fouling settling at GIND may be greater on a dry weight per unit area basis by a factor of 5 to 10 during any particular month of the settling season and by a factor of 6 to 7 over a 12 month immersion period.

6. The peak settlement periods of individual fouling species, although generally corresponding closely to the major fouling season at any one site, do not necessarily correspond exactly to it. Such a statement is applicable more to GIND than WND so that species with a spring or autumn settlement period at GIND are usually restricted in a summer settlement at WND.

7. The antifouling systems tested in this project (containing tributyltin as the toxic component) demonstrated reasonable resistance to fouling over 12 month immersion periods at GIND and WND.

8. 'Primary slimes' at WND initially consist of bacteria but after 10 to 20 days immersion the 'slime' is predominently diatomaceous.

9. Seasonal variations in the deposition of 'primary slimes' occur at WND although the qualitative composition of this 'slime' does not change greatly with season. The season of maximum 'slime' deposition corresponds with the season of maximum surface water temperatures.

6. SUMMARY

A comparison of the marine fouling occurring at the two principal Australian Naval Dockyards (Garden Island Naval Dockyard, Sydney Harbour, and Williamstown Naval Dockyard, Hobsons Bay) has been carried out. The sequences of change in the fouling communities settling on non-toxic panels immersed for periods of up to 12 months at each site are recorded and aspects of successional change in these communities are discussed. Aspects of seasonal variations in fouling intensity at each site are investigated and the fouling intensities (in terms of wet and dry weights of fouling per unit area per unit immersion time) at each site are compared. Finally the deposition of microfouling organisms ('primary slime') at WND is investigated. The composition of the slime and the seasonal variations in its deposition are recorded.

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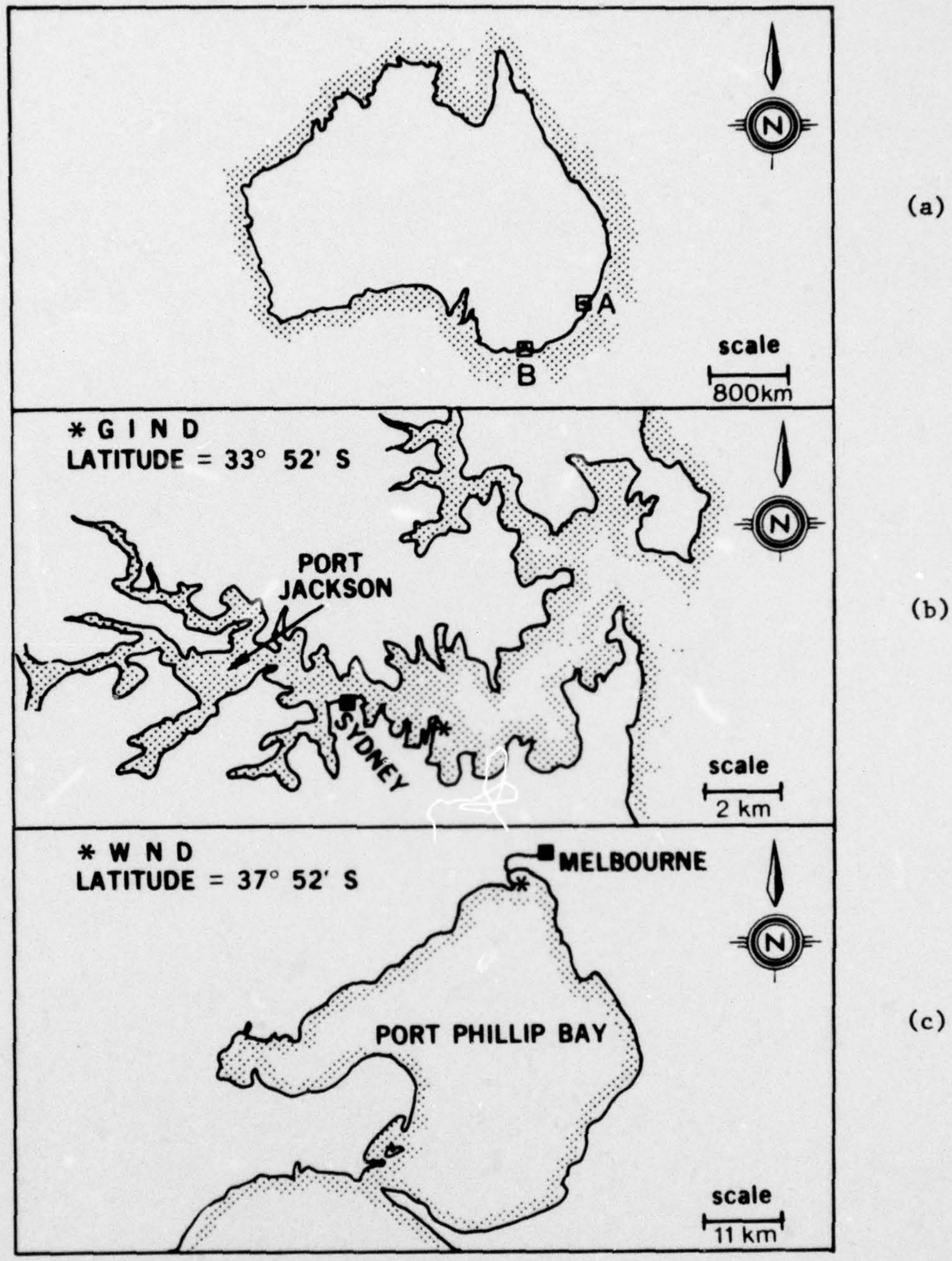


FIG. 1 - (a) Location of Garden Island and Williamstown Naval Dockyards on the east coast of Australia.

(b) Location of GIND within Port Jackson.

(c) Location of WND within Port Phillip.

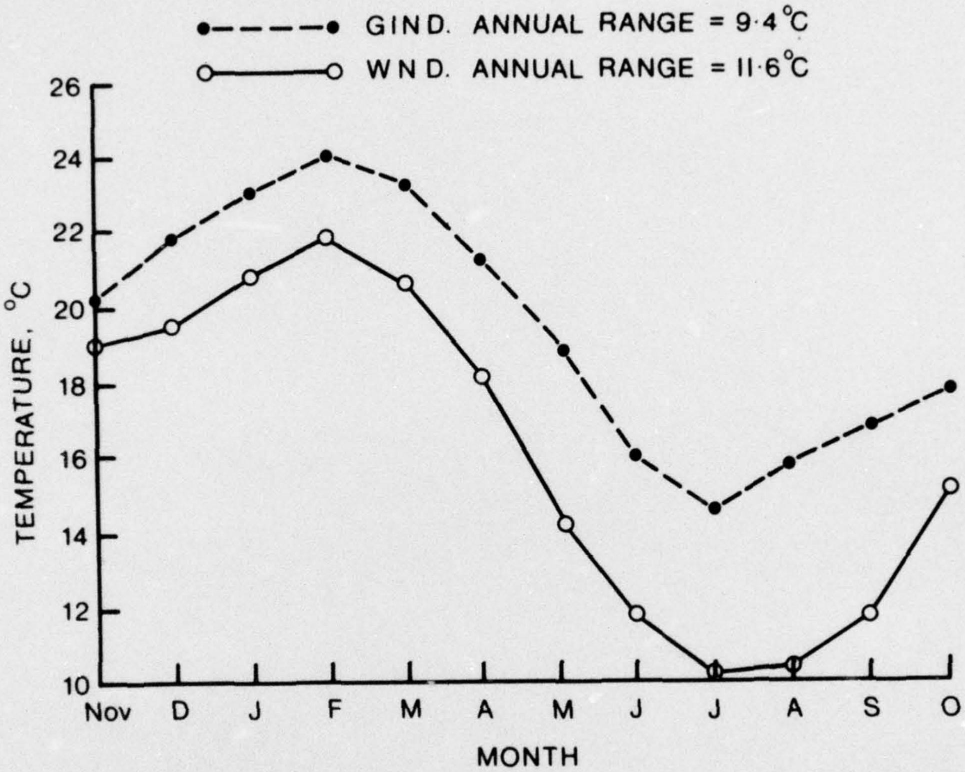


FIG. 2 - Average monthly surface water temperatures at Garden Island and Williamstown.

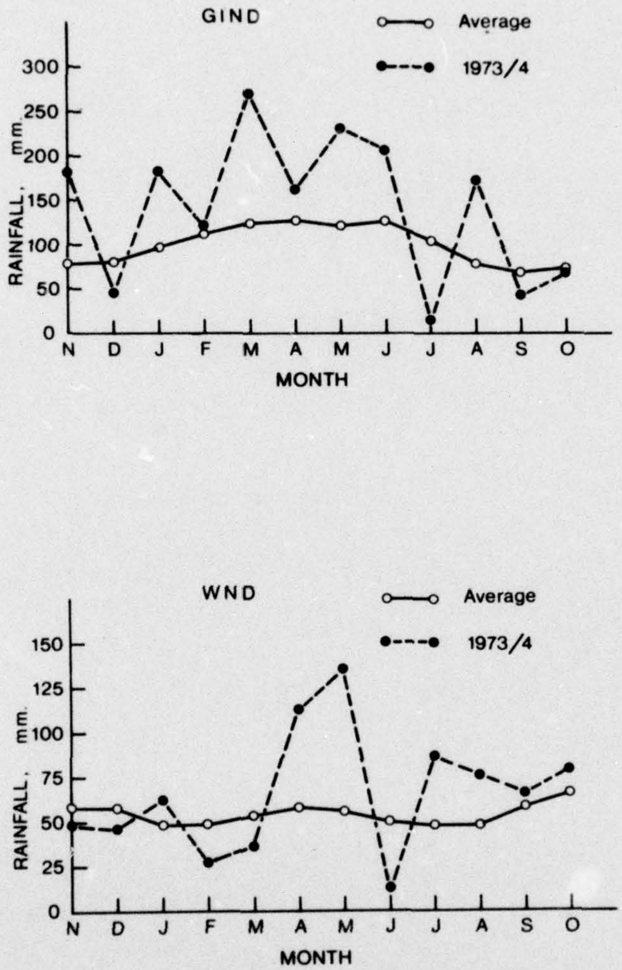


FIG. 3 - Average monthly rainfall data at GIND and WND, compared to 1973/74 values.

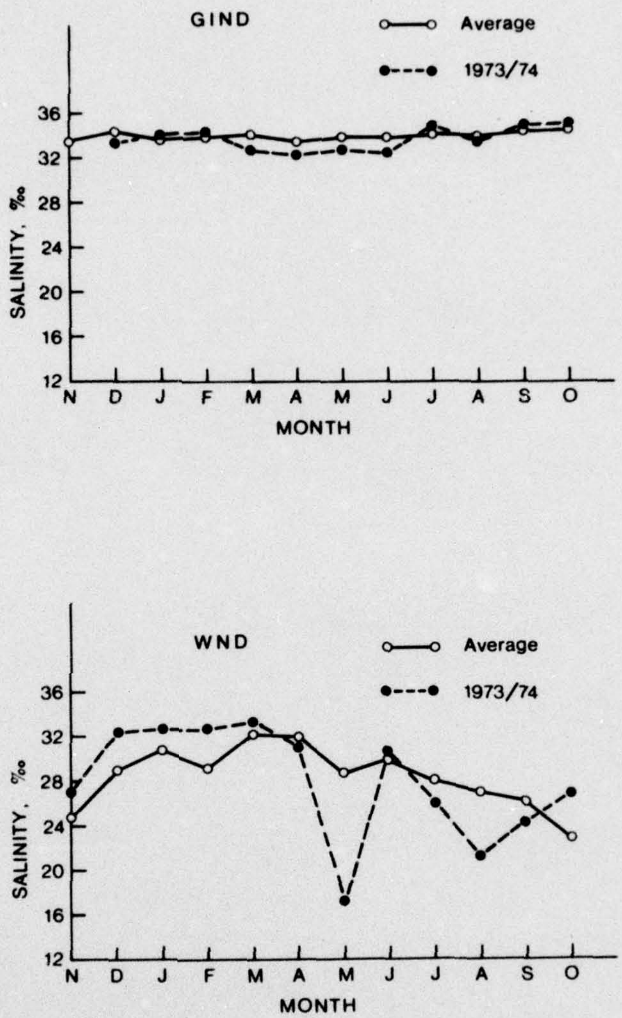
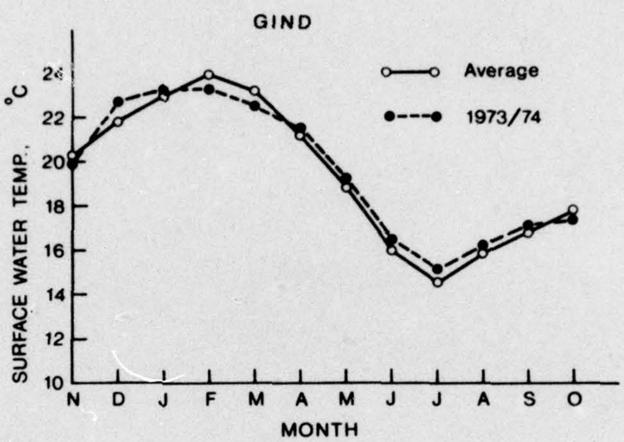


FIG. 3 - Average monthly salinity data at GIND and WND,
(Cont.) compared to 1973/74 values.



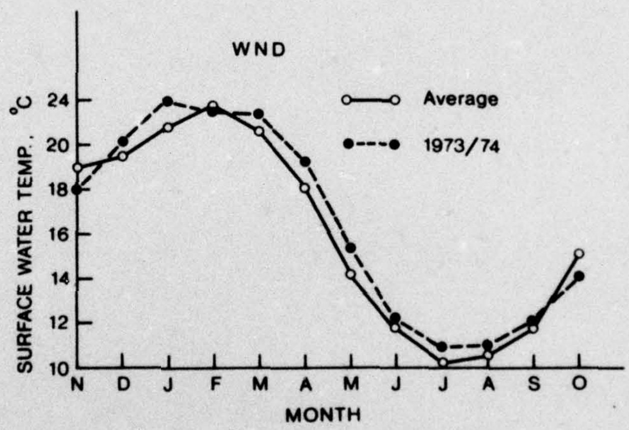


FIG. 3 - Average monthly water temperature data at GIND
(Cont.) and WND, compared to 1973/74 values.

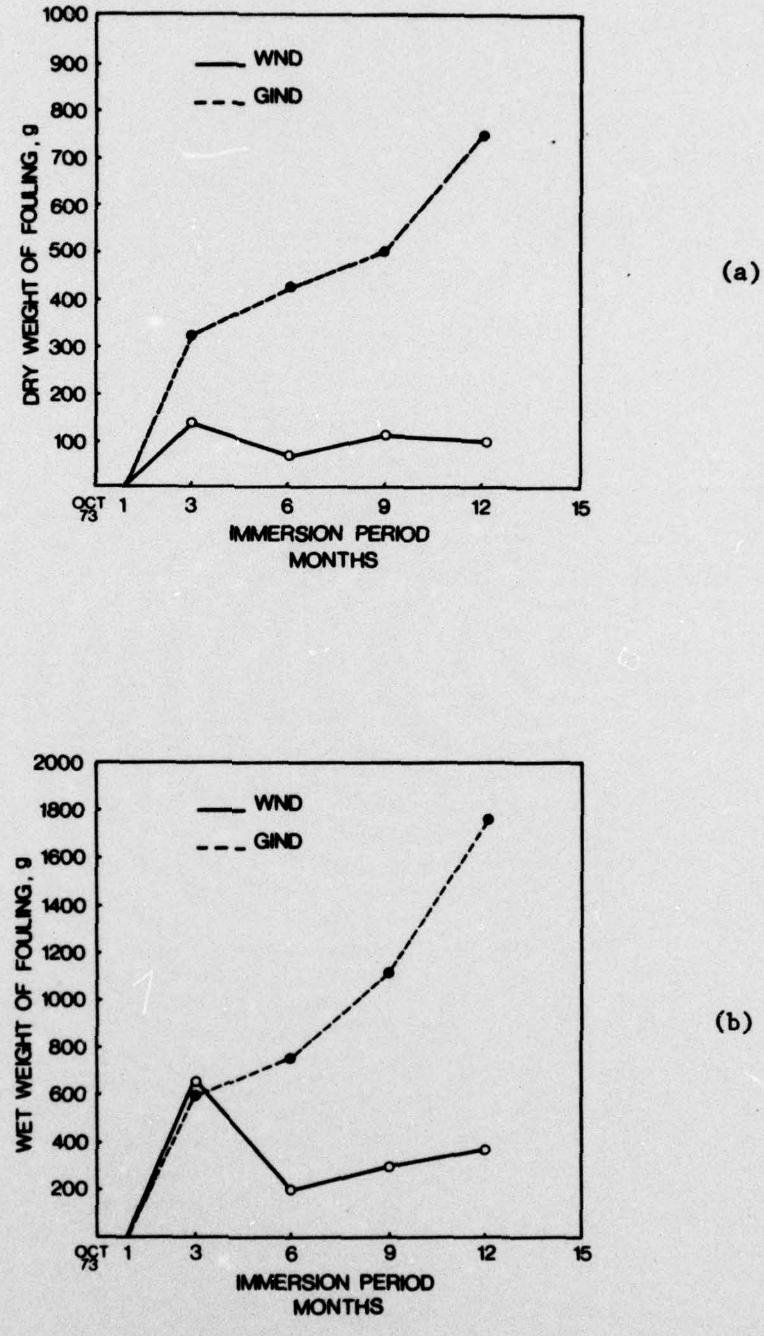


FIG. 4 - (a) Cumulative dry weight of fouling vs. immersion period for a steel panel (300 x 150 mm) at GIND and WND.

(b) Cumulative wet weight of fouling on the same panels for corresponding periods at the two sites.

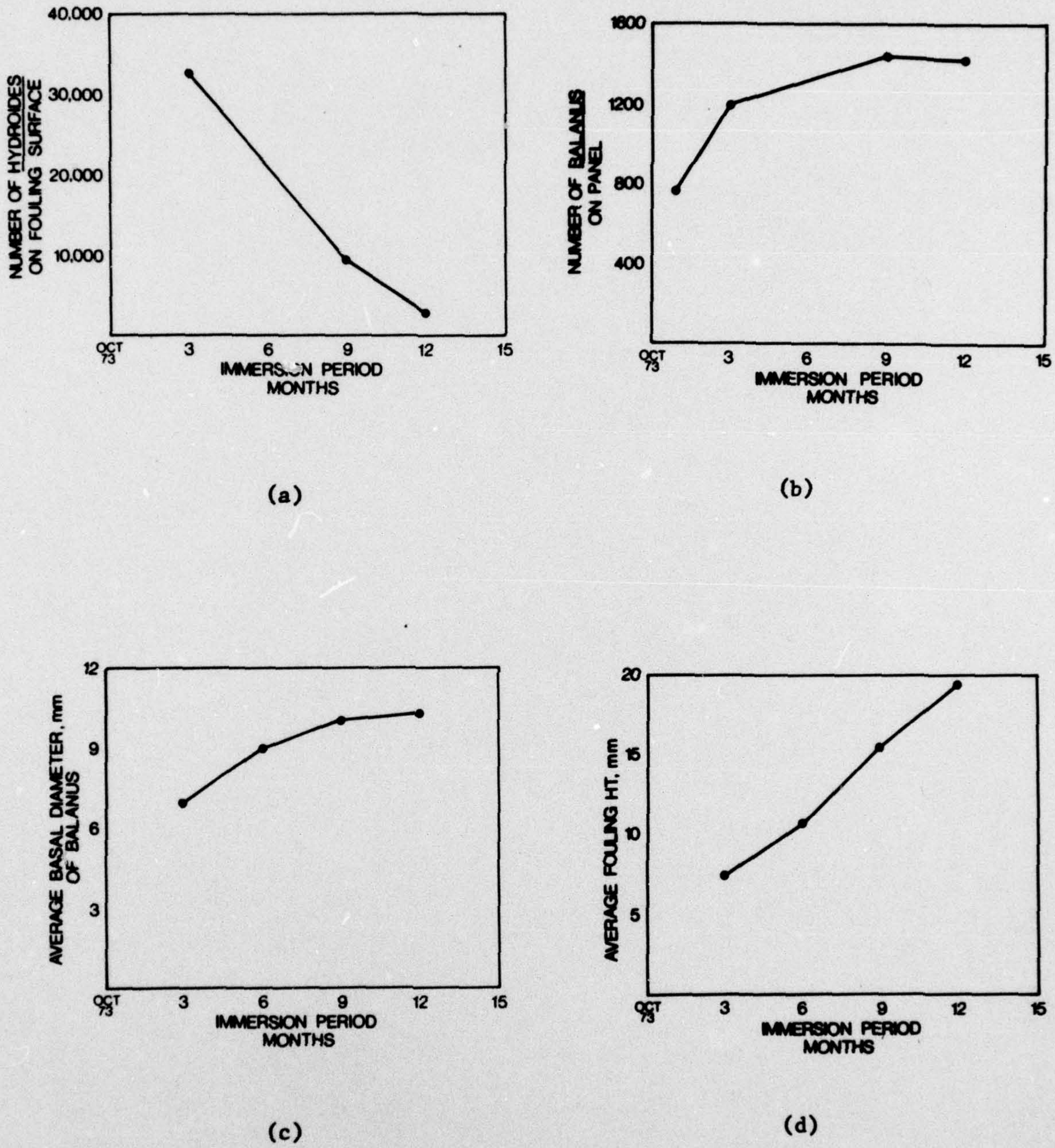


FIG. 5 (a-d) - Examples of major changes in fouling community structure at GIND.

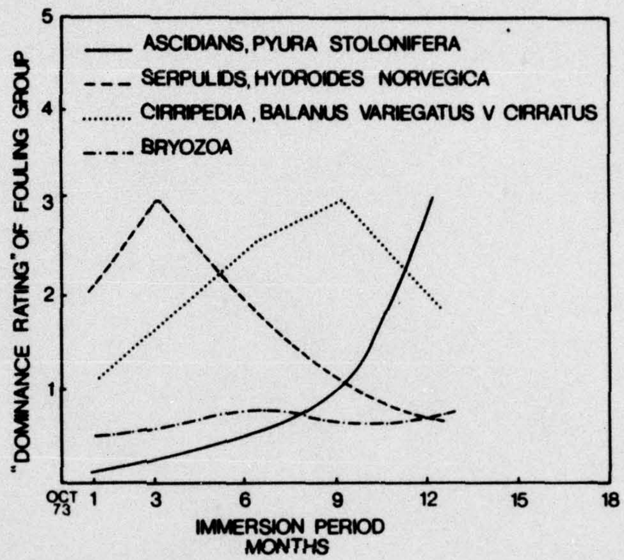


FIG. 6 - Changes in the dominant fouling community settling on panels immersed at GIND between October 1973 and October 1974.

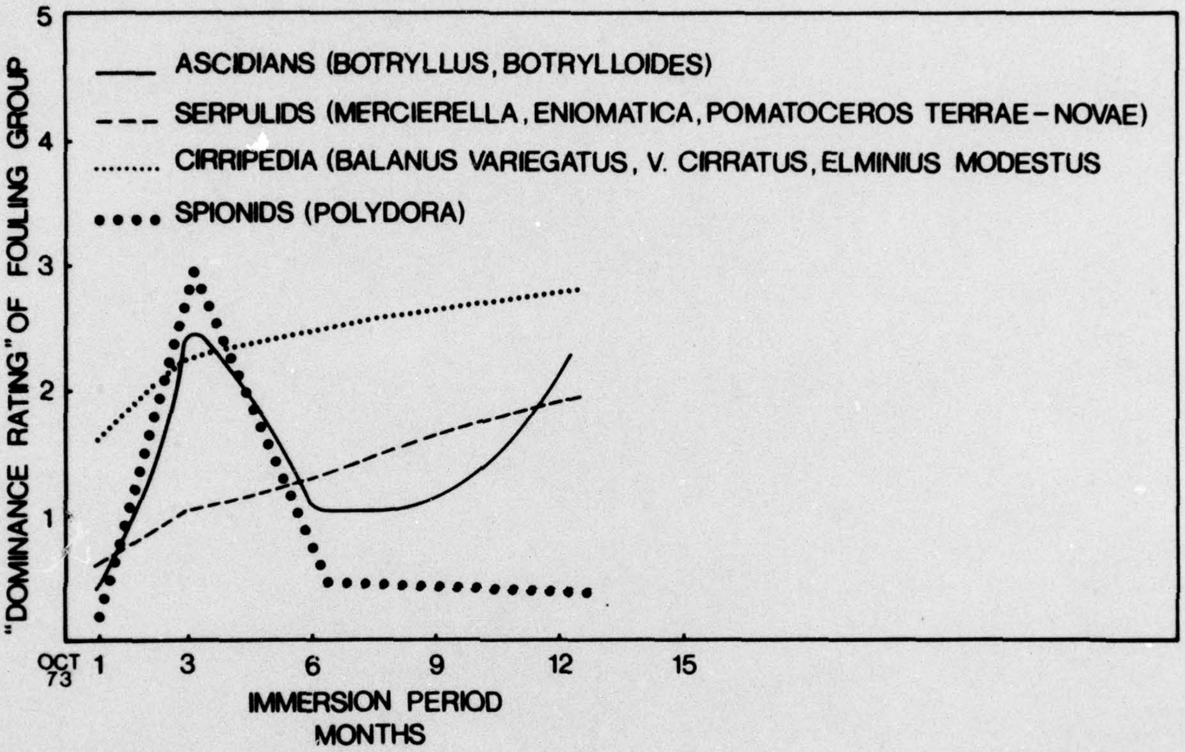


FIG. 7 - Changes in the dominant fouling community settling on panels immersed at WND between October 1973 and October 1974.

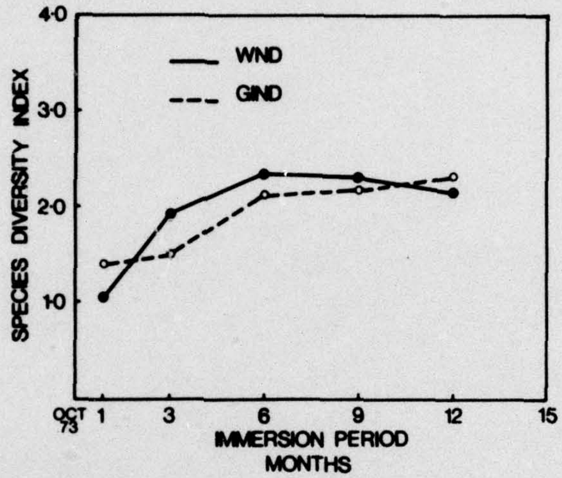


FIG. 8 - Species diversity index on panels immersed at GIND and WND for different periods.

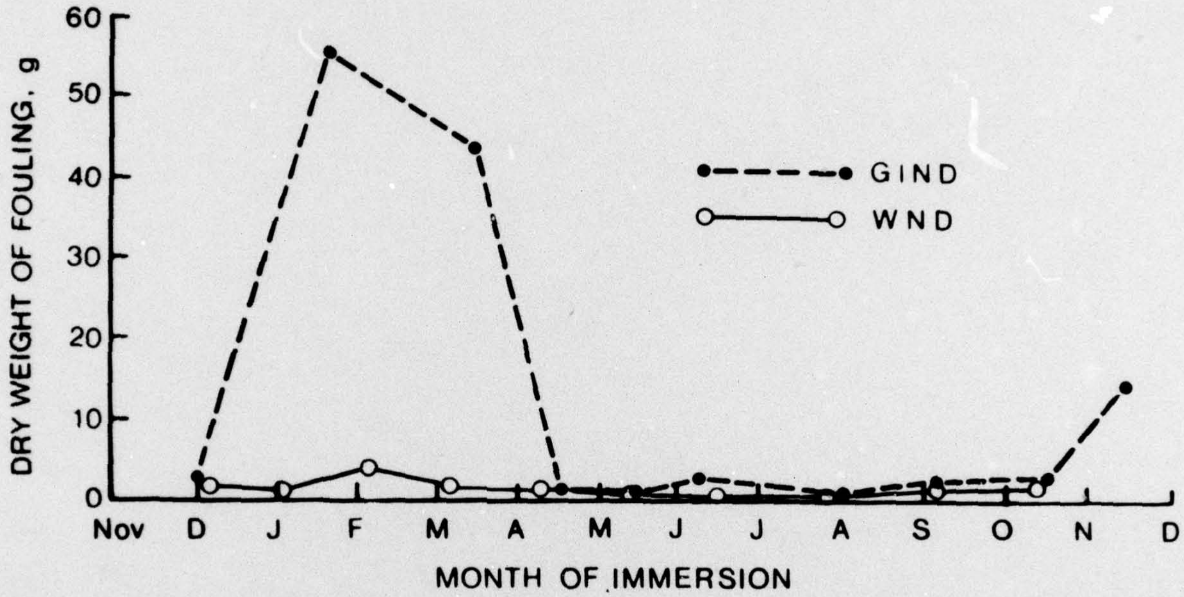


FIG. 9 - Changes in the monthly dry weight of fouling on PVC panels (300 x 150 mm) immersed at GIND and WND.

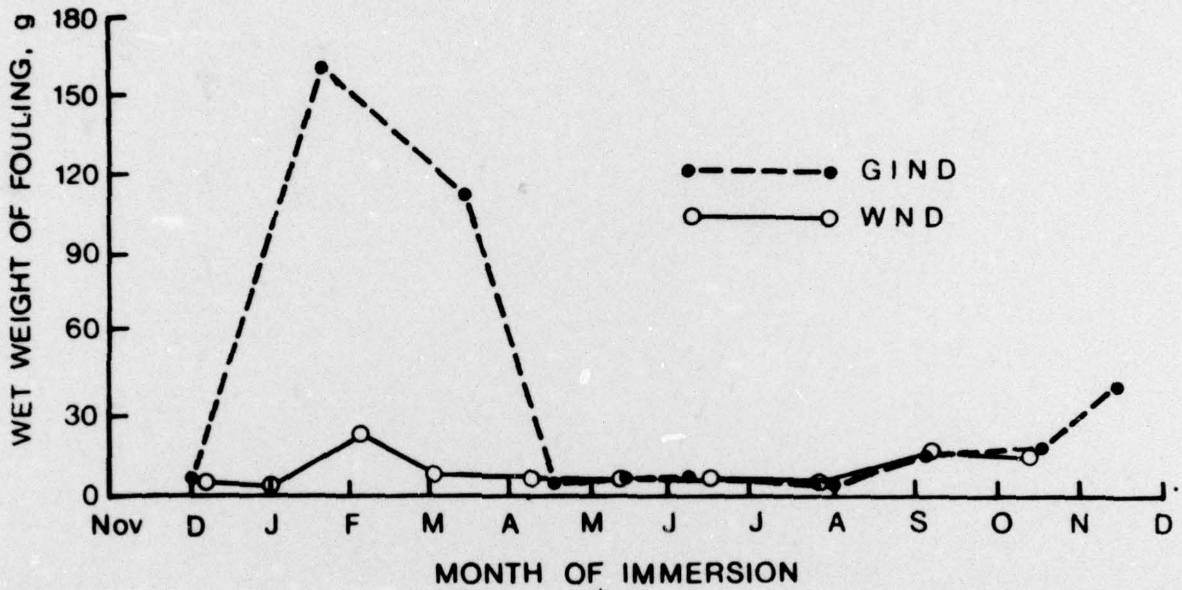


FIG. 10 - Changes in the monthly wet weight of fouling on PVC panels (300 x 150 mm) immersed at GIND and WND.

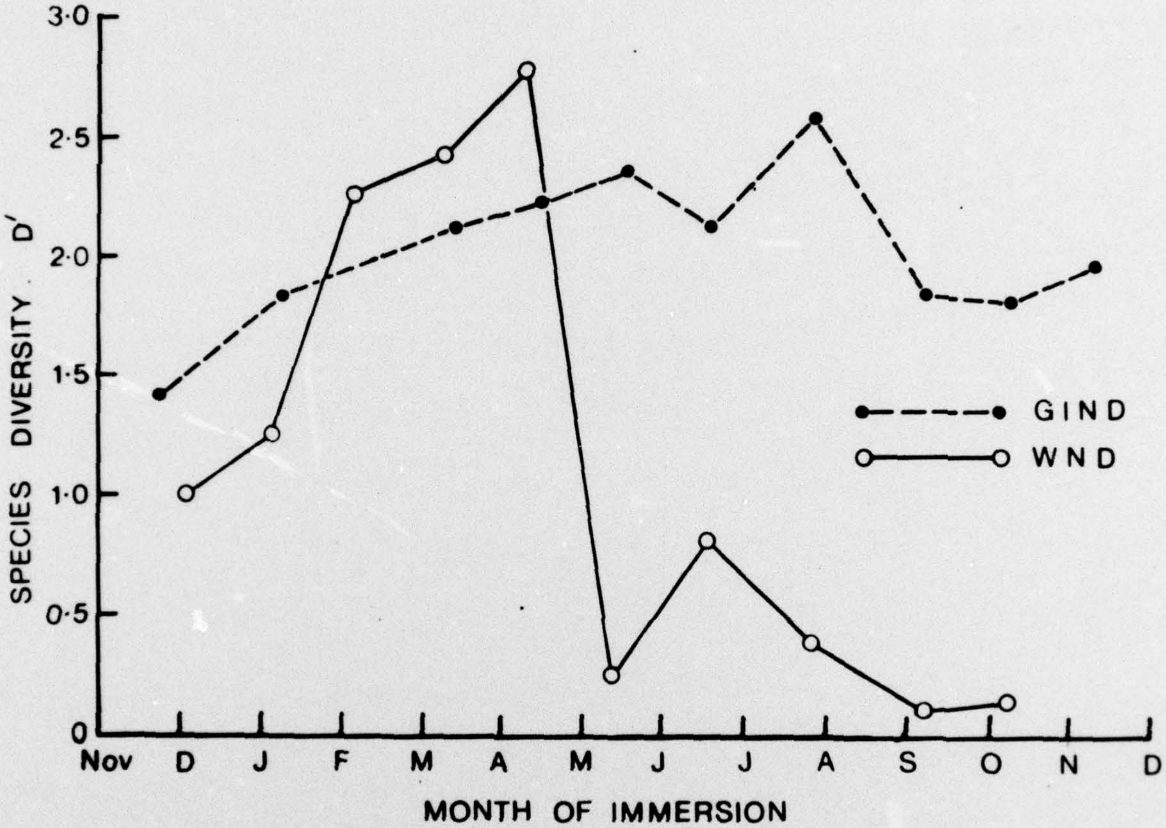


FIG. 11 - Species diversity index (D') of the fouling communities on panels after 1 month of immersion, during each month of the year at GIND and WND.

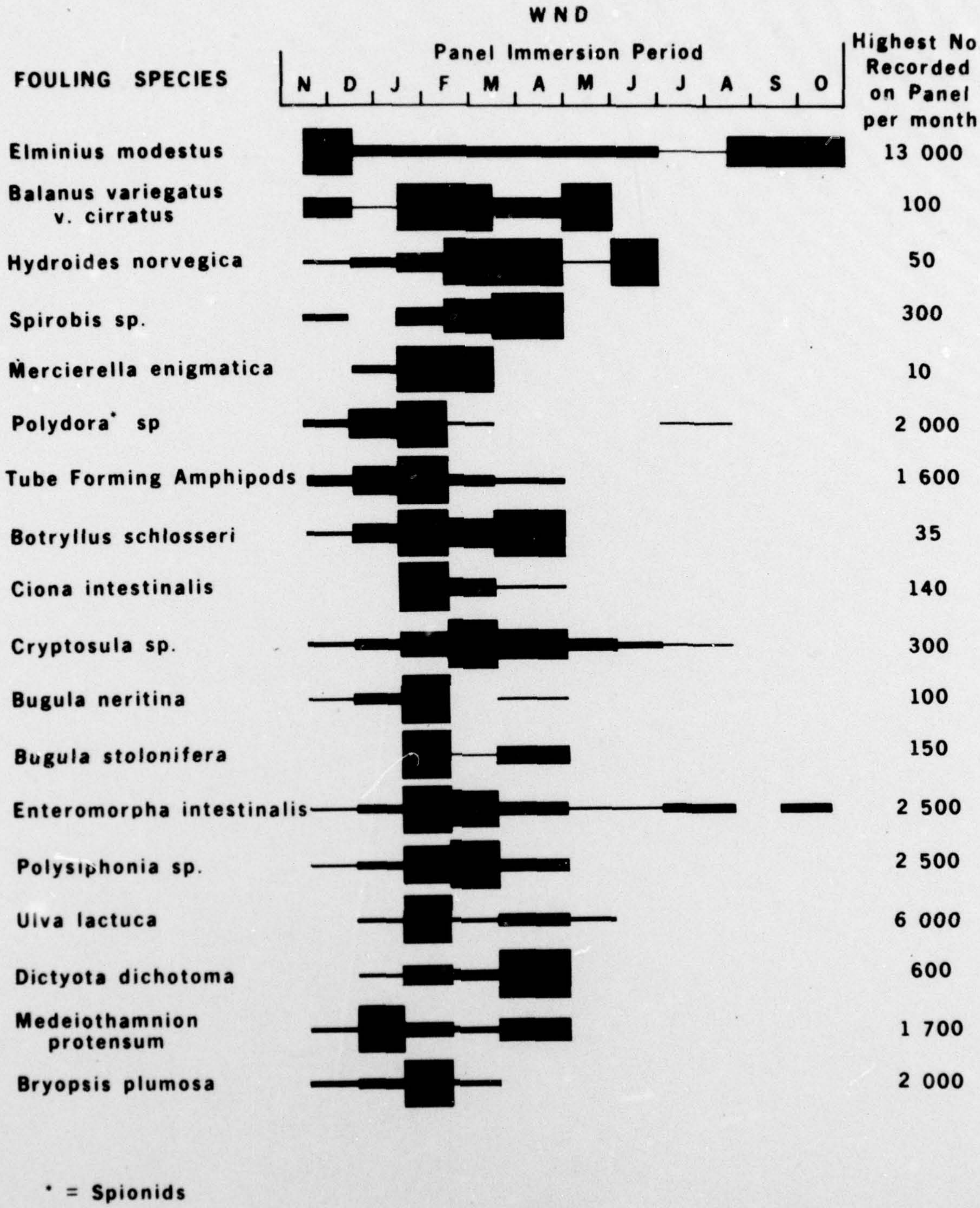


FIG. 12 - Seasonal variation in rates of settlement of principal marine fouling species during a 12 month period at WND (November 1973 - October 1974).

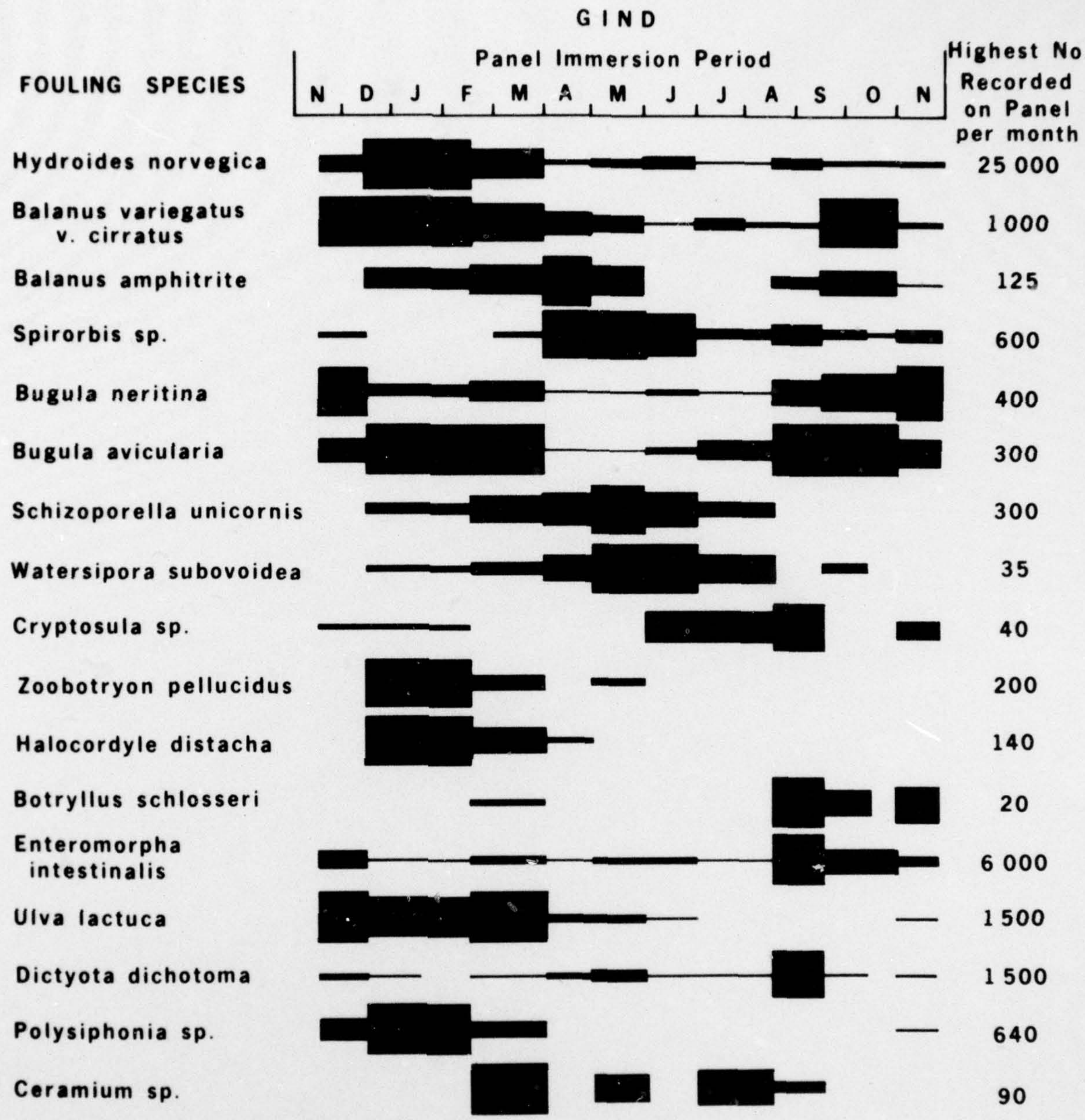
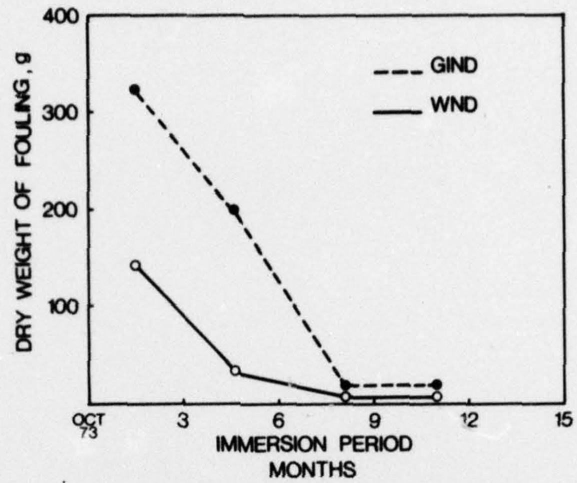
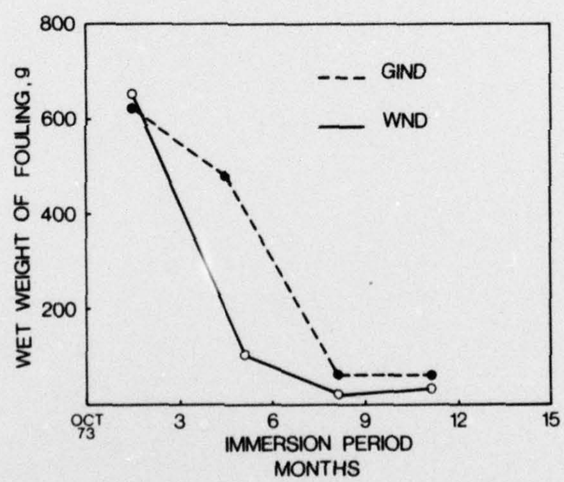


FIG. 13 - Seasonal variation in rates of settlement of principal marine fouling species during a 12 month period at GIND (November 1973 - October 1974).



(a)



(b)

FIG. 14 - (a) Dry weight of fouling on panels (300 x 150 mm) immersed for periods of 3 months at different times of the year.

(b) Wet weight of fouling on same panels.

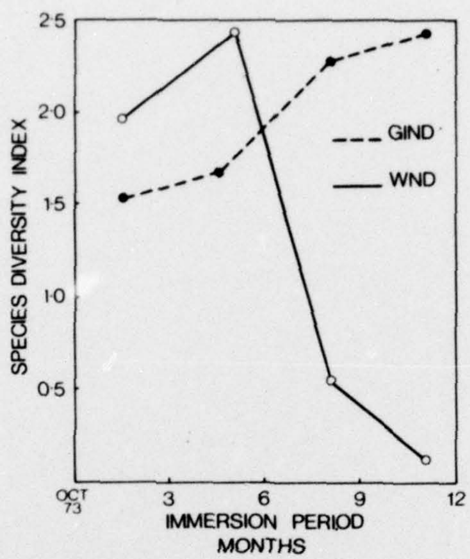


FIG. 15 - Species diversity index (D') for fouling communities settling on panels after 3 months immersion period during different times of the year at GIND and WND.

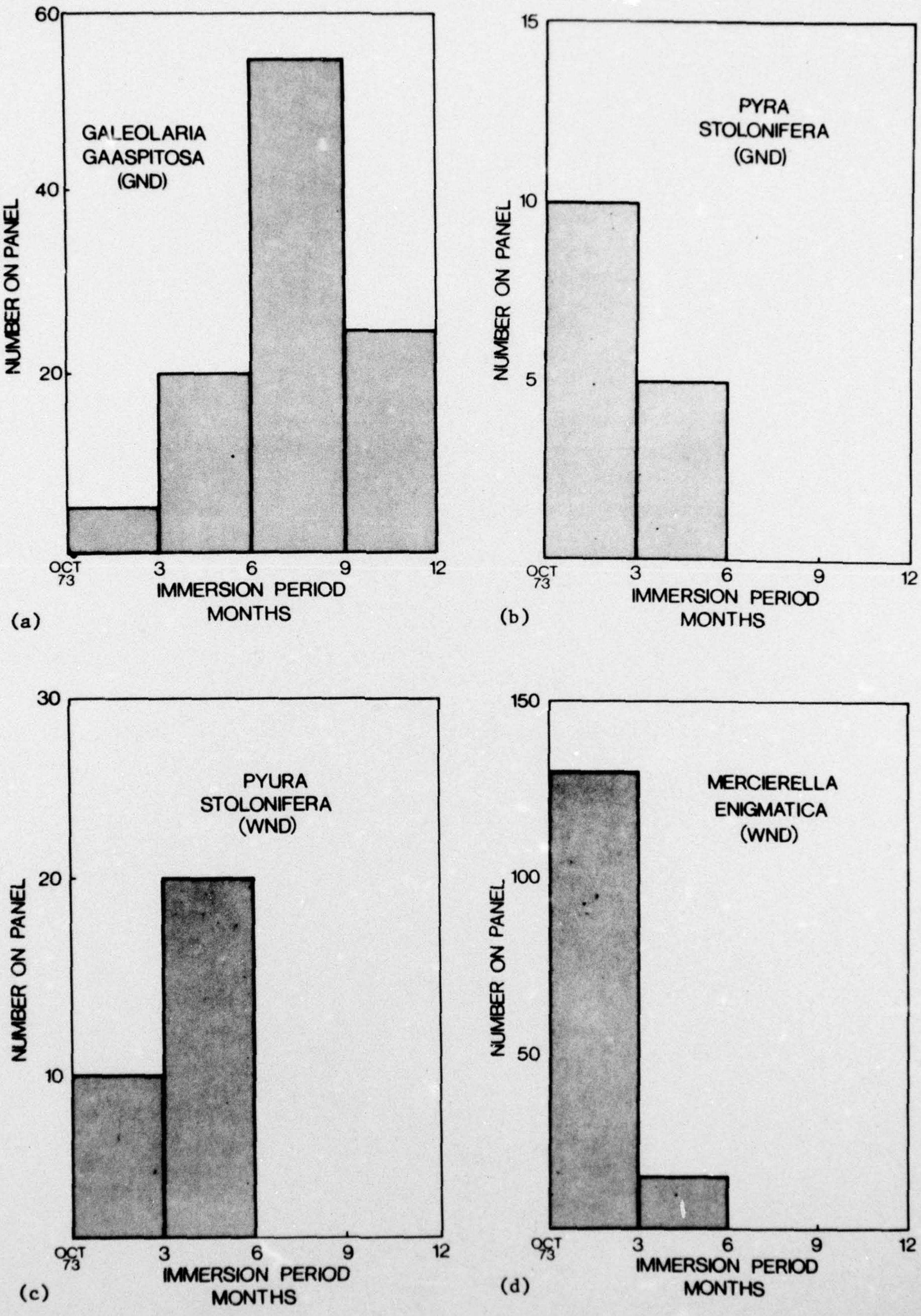
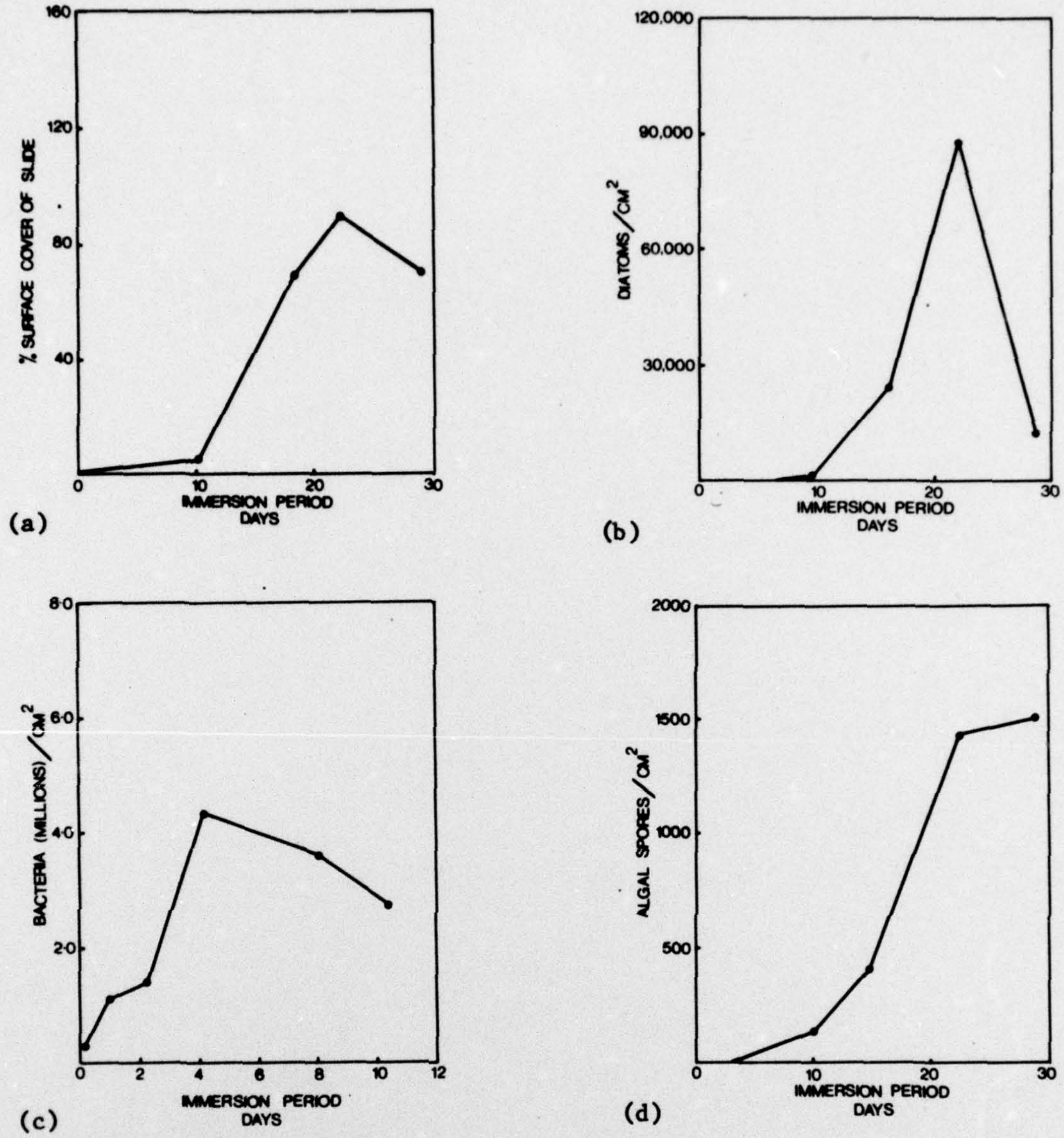


FIG. 16 (a-d) - Settlement rates for 3 major species over a 3 months immersion period during different times of the year.



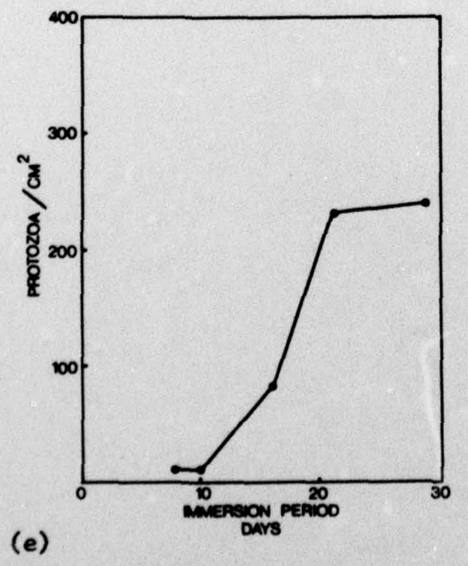
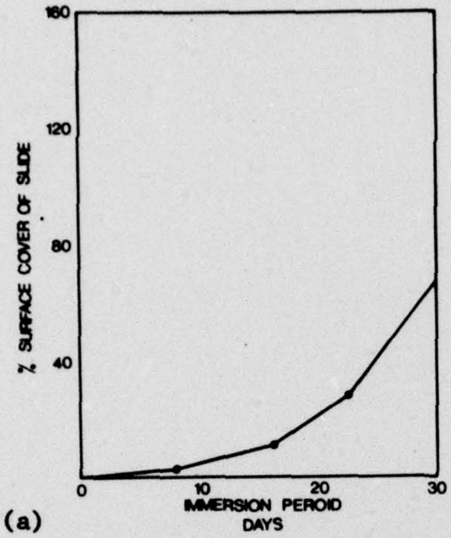
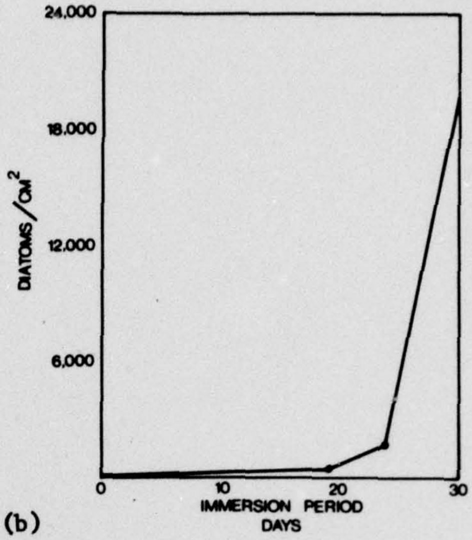


FIG. 17 (a-e)

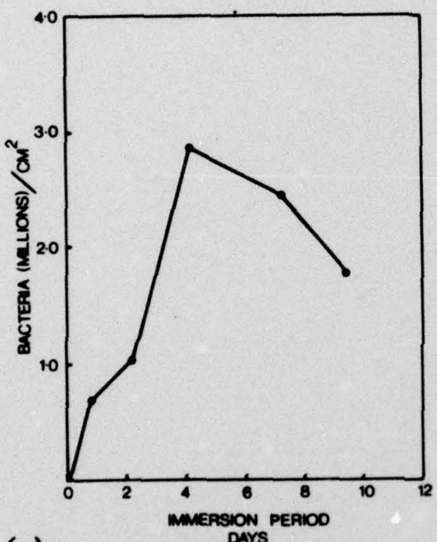
- Major changes in the composition of the "primary slime" during 30 days immersion at WND (25 February to 26 March 1974).



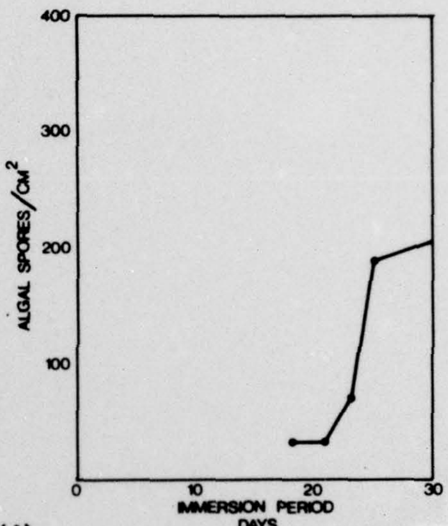
(a)



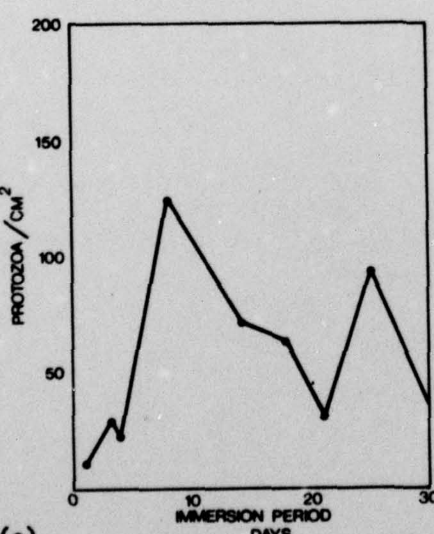
(b)



(c)



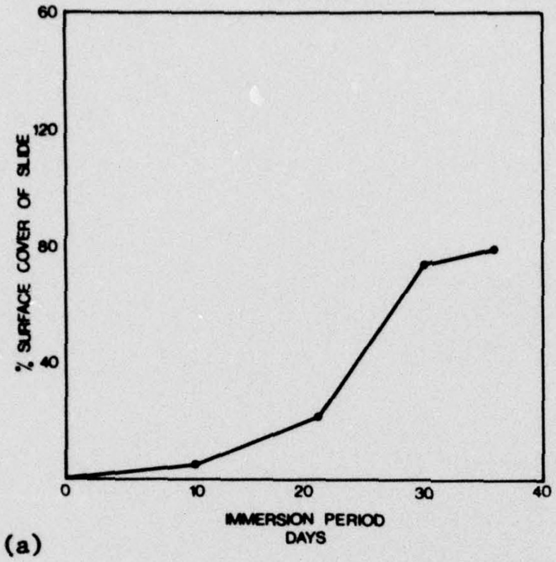
(d)



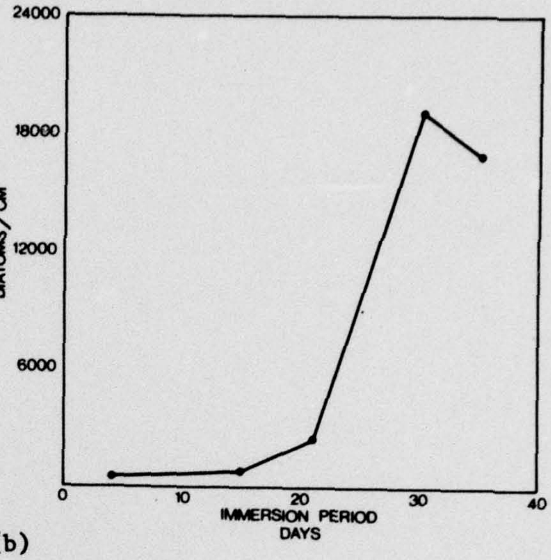
(e)

FIG. 18 (a-e)

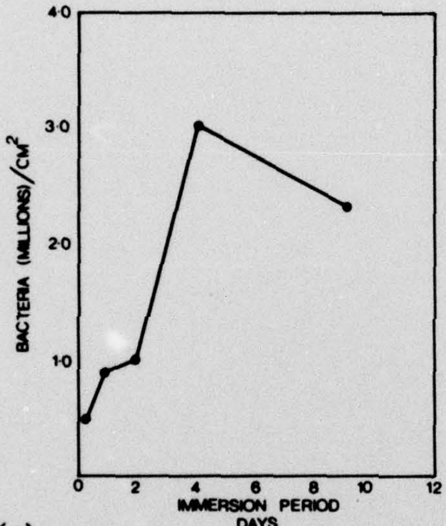
- Major changes in the composition of the "primary slime" during 30 days immersion at WND (6 May to 6 June 1974).



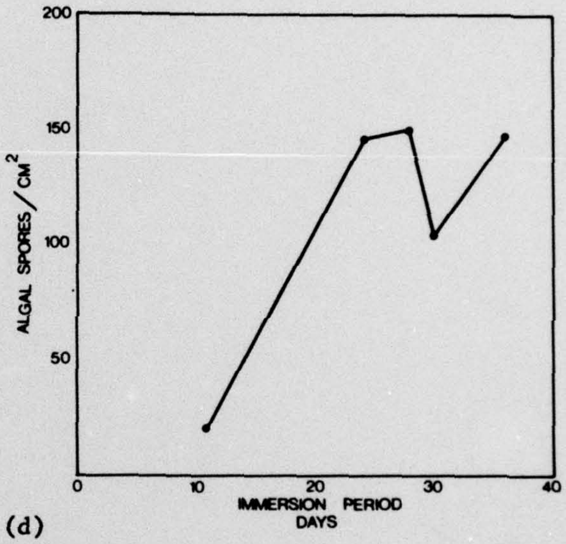
(a)



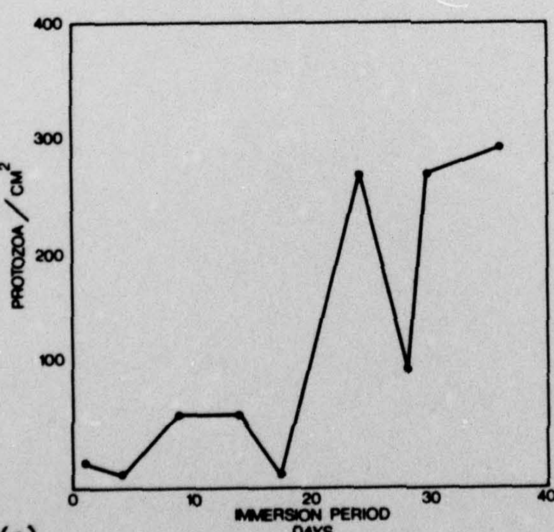
(b)



(c)



(d)



(e)

FIG. 19 (a-e)

- Major changes in the composition of the "primary slime" during 30 days immersion at WND (26 August to 1 October 1974).

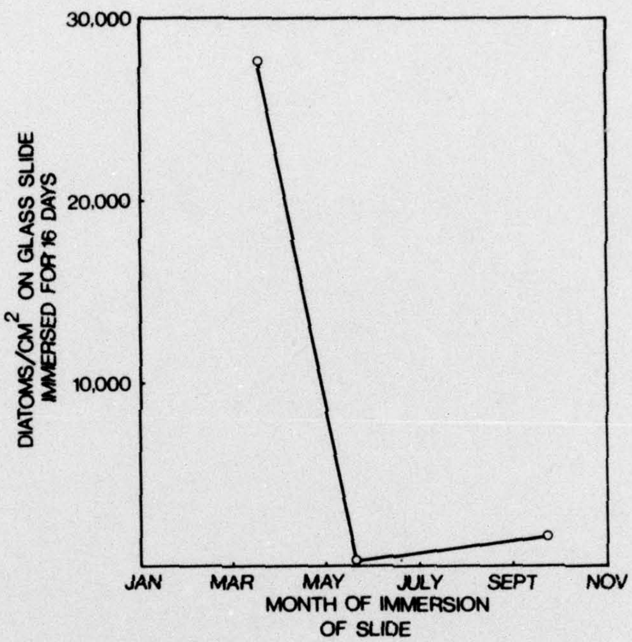


FIG. 20 - Number of diatoms per cm^2 attached to a glass slide after 16 days immersion at WND, at different times of the year.

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